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HON. EUGENE WHELAN, MINISTER
J.P. CONNELL, DEPUTY MINISTER

Note to readers: With this issue CFE has become a quarterly rather than a bimonthly journal. The first two issues of this year, winter and spring, were not published.

A comparative analysis of the egg grading industry in Ontario and Quebec

This paper analyzes the egg grading industry in Ontario and Quebec based on a framework provided by industrial organization theory. The paper describes the structure and conduct of this industry in the two leading egg production provinces and assesses their comparative economic performance.

Daniel Ricard

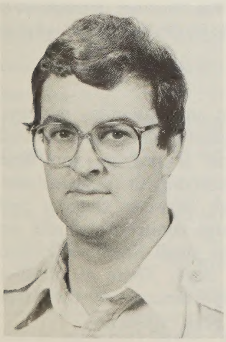
INTRODUCTION

Egg grading stations determine the size and quality of an egg so that buyers will be assured of a standardized, wholesome product. They are also a means for paying egg producers. The egg station or producer-grader is responsible for marketing the product to either retailers, wholesalers, processors, hotels, restaurants and institutions or even directly to the consumer. Any unsold surpluses are the responsibility of the provincial egg boards.

The large grading stations grade and pack eggs for the large retail chains. Normally their contract or working arrangement calls for them to supply a block of stores with all the eggs they need. Large stations can also supply the larger institutional outlets with loose-pack eggs (those stacked in trays containing 30 eggs).

The smaller egg stations serve the small stores in neighbouring towns and cities and handle the loose-pack trade in local markets by selling loose-pack eggs to institutions, caterers, restaurants, bakeries and stores which handle those eggs. They are also regional marketing points for producer-graded eggs, frequently assembling shipments of graded eggs for sale to larger egg stations.

This paper describes the structure and conduct of the egg grading industry in Ontario and Quebec and assesses their comparative economic performance. These two provinces lead the country in egg production. The study also describes the operations of the egg grading industry in each province and the effects of the provincial marketing structure on industry performance.



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BASIC CHARACTERISTICS

Characteristics of the Product

Demand for Eggs

According to the 1978 Family Food Expenditure Survey,[1] eggs account for only 1.9% of the average weekly food-at-home purchases of Canadians. They still remain, however, one of the most basic and versatile foods in the Canadian diet. They provide a good source of protein and other nutrients at a relatively low cost.

Agriculture Canada estimates that about 81–82% of the eggs produced in Canada pass through federally-registered egg grading stations and are routed to the retail level or to other intermediary levels such as hotels, restaurants and institutions (HRI). About 6.5% are kept for hatchery purposes while a little more than 10% come from non-regulated, small producers.[2] Approximately 2% of the eggs produced are leakers and rejects.

Based on the 1974 Family Food Expenditure Survey, the expenditure elasticities for eggs are +.0111 (all grades) and +.1482 (grade A).[3] The former estimate, however, is statistically insignificant. In a study undertaken for the Food Prices Review Board,[4] Spencer obtained an income elasticity for eggs of .06, also statistically insignificant. Other studies show that both price and income elasticities for eggs are close to zero, indicating that the demand for eggs is not very responsive to changes in those two variables. Egg demand is affected by variables which are not easily measurable. Health factors associated with cholesterol, changing consumer habits and the entry of more women in the work force may be partly responsible for changes in egg demand and for the inconclusive statistical estimations using standard demand equation variables.

Recent estimates of demand functions suggest that a statistically significant substitute for eggs is breakfast cereal.[5] The cross-price elasticity of demand for eggs with respect to the price of breakfast cereal is +.22.

Egg demand shows a degree of seasonality. Figure 1 indicates that egg disappearance is reaching a seasonal

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[1] *Urban Family Food Expenditure,* Catalogue No. 62-548, Statistics Canada, April 1980.

[2] Estimates provided by the Poultry Unit, Commodity Marketing Analysis Division, Agriculture Canada.

[3] Hassan, Z.A. and Johnson, S.R., *Urban Food Consumption Patterns in Canada,* Publication 77/1, Agriculture Canada.

[4] Spencer, B.G., *A preliminary Paper on Family Food Expenditure in Canada – An Analysis of the 1974 Survey,* Reference Paper 7, Food Prices Review Board, 1976.

[5] *Food and Agriculture Regional Model* (FARM) Part 11, Retail Demand, unpublished, Agriculture Canada.

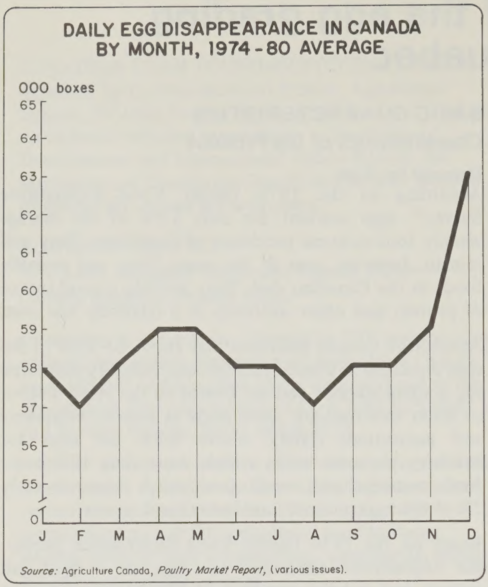

Figure 1

low every February and August and its highest peak in December when a lot of home baking takes place.

Rate of Growth

Per capita egg consumption in Canada has been slowly declining throughout the past 20 years, dropping from 23 doz in 1960 to 18.7 in 1980 (See Table 1). The trend is similar in the United States where consumption fell from 27.9 doz in 1960 to 22.7 in 1980.

Egg Grades

Each province has regulations governing grades and standards. Many, but not all, provinces have adopted the federal standard. The egg regulations established grade names, grade requirements and size designations for shell eggs.

Eggs are graded for interior quality and on the basis of size and shell cleanliness. The shell quality is an important factor in determining egg grades and it also reflects the ability of the shell not to crack during transportation. Canadian federal regulations which govern interprovincial and export trade provide for classifying shell eggs into four grades – Canada A1, A, B and C. Grading standards in some provinces have an additional grade called cracks. These eggs cannot be traded interprovincially.

Canada A1 and A are generally the only grades sold for fresh use to major retailers.[6] Canada B eggs are usually sold through farmers' markets, fruit stores and smaller grocery stores or are used in processing. Canada C eggs are eligible only for further processing, except in provinces where cracks, a subset of Canada C, are permitted to enter the table market.

[6] Between 1975 and 1979, about 93.7% of eggs marketed through registered grading stations in Canada were Grade A.

Nature of the Egg Supply

The trend in egg production is quite different from that of egg demand. Figures 1 and 2 reveal significant seasonal fluctuations arising from seasonal differences in both placements of day-old chicks and rate-of-lay. A hen starts to lay at approximately 5 months. The rate-of-lay generally peaks at about 7 to 8 months. Another factor which affects rate-of-lay among small flocks not subject to a controlled environment is the amount of day-light. Rate-of-lay tends to increase as the days get longer. The placements of day-old chicks in large commercial flocks peak in April-May. Among small flocks there is a minor peak in placements in October-November.

TABLE 1. DOMESTIC DISAPPEARANCE OF EGGS PER CAPITA

Year	Canada[a]	United States[b]
	doz	
1960	23.0	27.9
1961	22.6	27.3
1962	22.4	27.3
1963	21.5	26.5
1964	21.4	26.5
1965	21.2	26.2
1966	20.5	26.2
1967	20.8	26.7
1968	20.9	26.3
1969	21.4	25.8
1970	21.7	25.9
1971	21.3	25.9
1972	20.6	25.2
1973	19.7	24.1
1974	19.5	23.7
1975	19.4	23.0
1976	19.1	22.5
1977	18.6	22.3
1978	18.2	22.7
1979	18.9	23.1
1980	18.7	22.7

Sources: [a]Statistics Canada, Cat. No. 23-202.
[b]USDA Poultry and Egg Statistics through 1972, Statistical Bulletin 525; Poultry and Egg Situation for 1973-79.

As a result of the placement and rate-of-lay patterns, egg production reaches its highest peak in June, a period when smal flock production is peaking and large commercial flocks are still laying at a good rate. Production reaches a trough between October and December when the new, large commercial flocks are just beginning to lay and the small flock production drops because of shorter days. There is another production peak in January-February as the large commercial flocks reach their peak rate-of-lay.

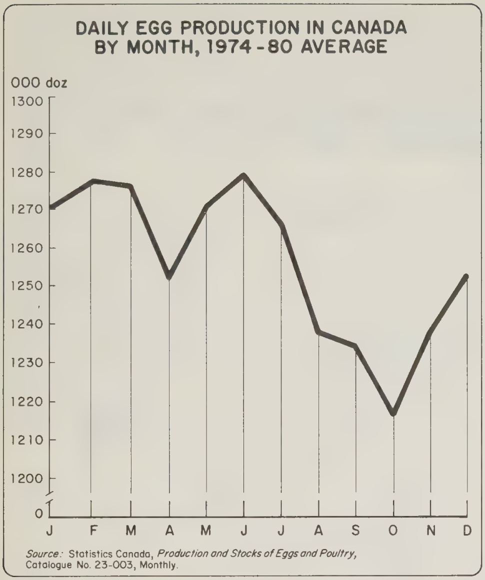

Figure 2

Freight costs make eggs a difficult product to carry over long distances. But this does not prohibit sizeable, interprovincial egg movement between provinces such as Manitoba, Ontario, Quebec and Alberta. Manitoba moves 31% of its egg grading receipts to other provinces (Table 2), whereas Quebec brings in approximately a volume equal to 30% of its egg grading receipts (Table 3). According to the proportion of egg grading station receipts, Manitoba is by far the province moving the largest volume of eggs interprovincially. This is partly why Manitoba was chosen to serve as the base point in CEMA's cost-of-production formula to determine the farm price of Canada grade A large eggs.

TABLE 2. INTERPROVINCIAL TRADE OF GRADED EGGS, 1981

Province	Outgoing Movement of Graded Eggs	Egg Grading Station Receipts	Outgoing Movement over Graded Receipts
	no.	$	%
British Columbia	1 700	3 478 883	0.04%
Alberta	60 829	2 242 052	2.70%
Saskatchewan	186 527	941 101	19.80%
Manitoba	871 797	2 823 601	30.90%
Ontario	1 204 754	11 095 358	10.90%
Quebec	27 807	4 324 737	0.60%
New Brunswick	47 282	505 766	9.30%
Nova Scotia	183 441	1 120 690	16.40%
Prince Edward Island	47 076	143 082	32.90%
Newfoundland	18 500	391 332	4.70%

Source: Agriculture Canada, *Poultry Market Report.*

Ontario's share of the national egg production quota of 38.2% is much larger than Quebec's 16.6%. In October 1980 there were 871 registered egg producers in Ontario and 350 in Quebec.[7] Farm cash receipts (1980) for eggs slated for consumption were $137 million for Ontario and $55 million for Quebec.[8]

TABLE 3. INTERPROVINCIAL TRADE OF GRADED EGGS, 1981

Province	Ingoing Movement of Graded Eggs	Egg Grading Station Receipts	Ingoing Movement over Graded Receipts
	no.	$	%
British Columbia	279 647	3 478 883	8.00!
Alberta	210 566	2 242 052	9.40%
Saskatchewan	51 922	941 101	2.30%
Manitoba	125 827	2 823 601	4.50%
Ontario	551 249	11 095 358	5.00%
Quebec	1 291 846	4 324 737	29.90%
New Brunswick	82 458	505 766	16.30%
Nova Scotia	9 000	1 120 690	0.80%
Prince Edward Island	—	143 082	—
Newfoundland	15 999	391 322	4.10%

Source: Agriculture Canada, *Poultry Market Report.*

Figure 3 shows the number of laying hens in Ontario and Quebec by county according to the 1976 Census of Agriculture. Egg production is concentrated mostly in southwestern Ontario and the Niagara Peninsula. In eastern Ontario there is also a secondary production region which is aimed primarily at supplying the Montreal market. Quebec's egg production is concentrated in the areas south of Quebec City (Dorchester, Levis and Beauce), south of Montreal (St. Hyacinthe and Drummond) and Joliette on the northern shore of the St. Lawrence. In Quebec, only one county – Dorchester – has a production base close to 500 000 hens. Production in Quebec is regionally less concentrated than in Ontario.

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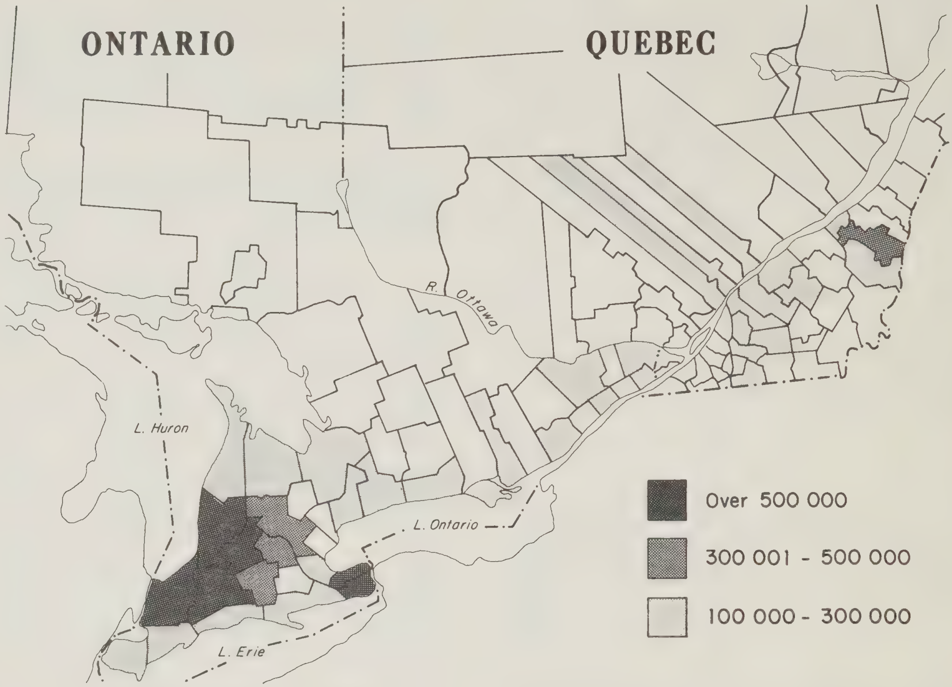
[7] National Farm Products Marketing Council.

[8] *Production of Poultry and Eggs,* Catalogue No. 23-202, Statistics Canada, 1980.

NUMBER OF HENS, FOR LAYING, FIVE MONTHS AND OLDER, ONTARIO AND QUEBEC, 1976



Source: Statistics Canada, *Census of Agriculture, 1976.*

Figure 3

More importantly, the size distribution of regulated egg producers is different from one province to the next. According to the National Farm Products Marketing Council's annual report for 1980, the average size of egg producer operations in Quebec was slightly larger than that in Ontario. In 1978, however, 18% of Ontario's quota was held by producers with quotas of 50 000 hens and more, whereas only 4% of quota in Quebec was held by these larger producers.[9] The size of the producers' operations and their concentration levels are partly due to differences in provincial quota administration policies, i.e., maximum size of quota ownership and unregulated flock size limits, as well as to a province's national quota share.

The Fédération des Producteurs d'Oeufs de Consommation du Québec (FEDCO) was set up in 1965, whereas the Ontario Egg Board was initiated in 1973, thus giving Ontario producers 8 more years to consolidate their operations. By the late 1960s and early 1970s it was common knowledge in the trade that Ontario would eventually get its egg board. Hence many producers in that province started to increase the size of their operations to ensure that they would eventually hold significant market quotas.

In both Ontario and Quebec, egg graders are located close to the supply source. According to the 1972 Report of the Royal Commission Appointed to Inquire into the Egg Industry in Ontario:

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[9] *Agro-alimentaire, La volaille et autres petits animaux d'élevage, état de la situation.* Les conférences socio-économiques du Québec, décembre 1979.

In each population center, the egg distribution system is fragmented into a number of production-marketing systems each centered around a grader, and which operate alongside one another with very little interaction or trade taking place. Groups of producers are rather permanently and inflexibly aligned to the grading station. Each egg grader, in turn, is rather permanently aligned with one or more regular customers, to whom a large proportion of eggs is shipped each week.[10]

There are two important reasons for these rather inflexible arrangements. First, with the use of automated grading equipment, efficiency requires continuous, near capacity operations.[11] To reduce shutdowns, large lots are desirable. This results in a much closer permanent relationship of egg producers with a specific grading station. However, the flexibility of this relationship seems to be increasing recently as evidenced by a larger number of premium payments and contests, etc. This may reflect excess capacity in the egg grading industry.

Second, as product is extremely perishable and as there is little room in an egg grading station to store inventory, egg graders have very little elbow room to negotiate with other retailers. Similarly, retailers must be guaranteed supplies. As eggs are required at least biweekly, this type of arrangement is deemed necessary by both grader and retailer.

Nature of Market Environment

Public Policy

The Institutional Framework

Canada's egg industry is regulated both provincially and nationally. Under the terms of the British North America Act, a province can regulate the marketing of farm products solely within its own boundaries, whereas international and interprovincial trade fall under federal legislation.

With the Agricultural Products Marketing Act of 1949, the federal government was able to provide provincial marketing boards authority to regulate interprovincial and export trade of its products (along with powers to collect levies). Howevers, it was not until the enactment of the Farm Products Marketing Agencies Act (FPMAA) in 1972 that national marketing boards with powers of Canadian supply management could be established. Before the implementation of the FPMAA, provincial boards lacked the authority to control interprovincial egg movement and attempts by some provinces to dispose of their surplus production led to the chicken and egg war which flared up between Ontario and Quebec in the early 1970s.

[10] Ross, J. F.W., *Report of the Royal Commission Appointed to Inquire into the Egg Industry in Ontario,* April 5, 1972, p. 62.

[11] Egg grading stations usually hire unskilled or semi-skilled labor. Labor costs are generally not very high.

The FPMAA is administered by the National Farm Products Marketing Council which is comprised of government appointed members, at least 50% of which must be primary producers. Membership on the council comprises a minimum of three representatives and a maximum of nine. In 1981 there were nine appointees. There is also an attempt to have regional representation – one-third from western provinces, one-third from the two central provinces and one-third from the four eastern provinces.

Pursuant to the above mentioned federal legislation and with the aid of other provincial legislation, the 10 provinces and the federal government signed the Comprehensive Federal-Provincial Agreement to establish a marketing program for eggs in November 1972. This agreement established the Canadian Egg Marketing Agency (CEMA) in December of the same year.

With the CEMA proclamation, the National Egg Marketing Plan was established as part of the agreement. Its purpose is to ensure orderly egg marketing in Canada, a fair return to producers, a dependable supply of high quality eggs to the consumer and the cooperation and the coordination between the various provincial egg marketing boards and CEMA.

Figure 4 illustrates the regulatory and operational framework of the egg industry.[12] As seen from this figure, CEMA determines regulated egg production and its responsible for ensuring that provincial allocations are made in accordance with the terms set forth in the federal-provincial agreements. Each province's market share was determined on an historical basis by taking the average of the previous 5 year's production (1967-71). Each provincial marketing board had the responsibility of dividing the total provincial allocation of eggs among the province's producers by means of a quota.

Quotas were originally set according to egg numbers, but since many producers grade their own eggs and sell them directly to the consumer, it soon became evident that this type of monitoring would be impractical. The resulting statistics and records were often sharply disputed. As a result, quotas were converted to an equivalent number of hens permitted each producer. A producer's quota is now defined as all the eggs he is able to produce from a given number of hens. This system is simpler to monitor.

CEMA establishes the price for Grade A large eggs in all provinces according to a cost-of-production formula. Quebec, however, believes that this is still a matter of provincial responsibility. CEMA is also the sole seller of declared surplus egg supplies to egg processors, otherwise known as breakers, and to the table market. Only 1-2% of these breakers go back to the table market. CEMA ensures that each province does not produce

[12] *The Egg Industry in Ontario,* Ontario Ministry of Agriculture and Food, June 1970.

Institutional Setting in the Canadian Egg Industry

Source: Adapted from Minutes of Proceeding and Evidence of the Special Committee on Egg marketing, House of Commons, Ottawa, Issue No. 16 (Dec. 1974), p. 8.

Figure 4

more than its allocated quota and removes from the market the eggs in excess of provincial requirements and interprovincial movement undertaken by the trade. CEMA monitors hen counts and levies a penalty of $1.00 a bird per month for every bird above quota. In addition, CEMA was given powers to license persons involved in egg marketing in inter-provincial or export trade and to collect fees for these licenses.

The provincial boards are responsible for setting their own quota allocation method among producers and scheduling production within the province. By a judgement of the Supreme Court of Canada in January 1978, each provincial board is allowed to impose a levy on eggs marketed intraprovincially, whereas CEMA can impose a levy on eggs marketed in interprovincial and export trade. The provinces are not unanimous in their interpretation of the Supreme Court's judgement with respect to responsibilities, control of surplus removal and levy collection. In practice, two levies are collected – one to be used by the provincial board and the other by CEMA to defray surplus removal and administration costs. Some provinces believe that CEMA acts as the provincial board agent in surplus disposal and levy collection.

Quebec was the first province to establish its own egg marketing board, FEDCO, in 1965. At the time, Quebec felt the need for an egg marketing board because its small egg industry was threatened by neighboring Ontario, which instituted its own board in January 1973.[13] FEDCO set out to accomplish the objectives of any marketing board – (1) to preserve the family farm as a viable economic unit, (2) to counterbalance the market power held by large retailers and (3) to generally improve the quality of the province's egg grading industry.

In addition to its role as a producer organization, FEDCO set up a sales agency in 1968 to sell all eggs produced within FEDCO-designated areas. FEDCO believed that some producers were pressuring other producers to have their eggs graded in their establishments and were even overcharging them for this service.

It was not until 1975, however, that this agency was able to exercise its full powers. FEDCO initially divided the province into 16 areas or zones with the intention of centering producer activity exclusively around an egg station over which it would exercise full control through an operating contract. By 1981 there were only nine such designated zones left, but it is believed that producers within these nine zones can provide more than 80% of the eggs in Quebec. Some producers later received authorization from the Régie des Marchés Agricoles to remain as producer-graders. Any producer-grader wishing to engage in interprovincial trade required federal licensing.

The Quebec legislation also provides for a committee which meets on an *ad hoc* basis to set wholesale prices. The Régie des Marchés Agricoles names a permanent arbiter to settle any disputes which could arise between representatives of FEDCO and the retail sector.

Marketing Channels

In Quebec, approximately 49% of all egg marketings in federally-registered egg stations were routed through FEDCO-controlled stations in 1981. Throughout the 1970s, FEDCO's share of Quebec egg gradings was higher – 56% in 1975 and 60% in 1971.[14] It appears that the closure of two FEDCO-controlled stations in the early 1980s has contributed to FEDCO's decreasing share of the market. There are now eight FEDCO-controlled stations in Quebec. Producer-graders have assumed a larger share of total egg marketing in Quebec and have continued to increase their share during this period.

Registered egg stations in Ontario received 90.7% of production in 1977; 1.4% was consumed on farms and the remaining 7.9% sold directly by producer-graders and unregulated producers (i.e., those with less than 500 laying hens).[15] Conversations with officials of the Ontario Egg Board reveal that these shares were relatively constant throughout the 1970s.

Pricing System at the Farm Level

Many provinces delegated to CEMA the authority to set prices for Grade A large eggs across Canada. To accomplish this, CEMA asked an independent consultant to carry out a cost-of-production study which included a national survey of regulated egg producers in Canada. (A formula based on the study is shown in Table 4.) Only producer flocks ranging between 10 000 and 50 000 birds were included in the survey sample.

The formula categorizes the costs of producing a dozen eggs into five elements – depreciation, pullets, feed, labor and overhead. The formula allows for regional differences in cost components. Pullets, feed and labor costs comprise nearly 80% of the total cost. The following additional components are added to the actual farm gate costs:

1. A consumer subsidy for processing.
2. An administration levy. This cost component includes charges for the supply management program at both provincial and national levels to ensure effective operation.
3. A conversion factor to arrive at a price for Grade A large.

The sum of the five cost components and the three pricing adjustments represent the farm gate cost for each province. To arrive at a national average cost, each

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[13] Quebec was late is instituting its marketing board for chicken, whereas Ontario had already started its own chicken marketing board in the early 1960s.

[14] Food Production and Inspection Branch, Agriculture Canada.

[15] *The egg industry in Ontario, op. cit.*

TABLE 4. COST OF PRODUCTION SUMMARY AS OF OCTOBER 8, 1980 (Effective October 13, 1980)

Prov.	Deprec.[a]	Pullet Cost[a]	Feed Cost[b]	Labor[b]	Overhead[c]	Consumer Subsidy Process	Admin. Levies	Convrsn. to Large[a]	Total Farm Gate[b]	% Market Share	Provincial Contr. to Nat. Ave[d]	Base Price Man.[b]	Freight v.s. Man.[e]	Handling v.s. Man.[e]	Producer Price A Large[b]
							cents per dozen								
B.C.	3.12	13.37	38.87	7.04	7.65	2.5	2.5	6.97	82.02	12.055	9.888	85	7.0	3.0	95
Alta.	3.12	13.62	40.94	6.62	7.65	2.5	2.5	6.97	93.92	8.705	7.305	85	6.0	2.0	93
Sask.	3.12	13.97	42.42	6.45	7.65	2.5	2.5	6.97	85.58	4.760	4.074	85	5.0	2.0	92
Man.	3.12	13.52	40.32	6.05	7.65	2.5	2.5	6.97	82.63	11.408	9.426	85	—	—	85
Ont.	3.12	13.38	43.74	5.63	7.65	2.5	2.5	6.97	85.49	38.161	32.624	85	4.0	1.0	90
P.Q.	3.12	13.65	47.18	5.39	7.65	2.5	2 5	6.97	88.96	16.556	14.728	85	6.0	1.0	92
N.B.	3.12	15.15	47.95	5.14	7.65	2.5	2.5	6.97	90.98	1.828	1.663	85	8.0	3.0	96
N.S.	3.12	14.62	49.02	5.17	7.65	2.5	2.5	6.97	91.55	4.106	3.759	85	9.0	1.0	95
P.E.I.	3.12	14.86	50.39	5.13	7.65	2.5	2.5	6.97	93.12	0.637	0.593	95	3.0[f]	—	98
Nfld.	3.12	16.39	49.48	5.08	7.65	2.5	2.5	6.97	93.69	1.785	1.672	95	8.0[f]	—	103

[a]Recalculated quarterly.
[b]Recalculated monthly.
[c]Recalculated monthly to reflect changes in interest costs.
[d]The total of all figures in the column showing provincial contributions to the national average is 85.372¢. The addition of a producer return of 3.9¢ and the subtraction of freight and handling charges to Toronto of 5¢ results in a Manitoba base price of 85¢ (as shown in the next column).
[e]Estimated.
[f]Freight costs from Nova Scotia.

Note: All calculations are made in accordance with the July 1979 update of the P.S. Ross formula.

TABLE 5. PRODUCER, WHOLESALE AND RETAIL PRICES OF GRADE A LARGE EGGS IN TORONTO AND MONTREAL

	Toronto			Montreal		
	Producer Price	Wholesale Price	Retail Price	Producer Price	Wholesale Price	Retail Price
			¢/doz			
1971-1972 Crop Year						
September	28.2	41.5	–	35.6	50.8	–
October	25.0	38.8	–	32.2	47.1	–
November	29.4	43.0	–	34.5	48.0	–
December	34.0	47.6	–	38.6	52.1	–
January	28.2[a]	41.2	–	32.2[c]	46.6	–
February	20.5	33.8	–	24.2	36.7	–
March	22.8	36.5	–	28.0	40.9	–
April	27.0	40.6	–	31.0	43.1	–
May	25.8	38.8	–	27.2	40.3	–
June	26.3	39.5	–	26.4	39.8	–
July	35.4	48.4	–	36.8	50.3	–
August	28.1	51.7	–	39.6	52.8	–
1979-1980 Crop Year						
September	80.0	95.9	100.7	82.0	101.3	105.7
October	90.5	96.6	101.4	82.5	102.4	107.5
November	81.0	97.2	102.0	81.0	103.3	105.6
December	80.4	96.6	103.0	80.4	102.8	107.0
January	81.5	98.5	105.1	83.5	103.8	109.5
February	83.0	99.8	106.6	85.0	105.2	112.3
March	82.4	99.3	106.3	84.4	104.5	112.2
April	82.5	99.6	107.8	84.5	104.2	111.9
May	82.5	99.5	106.5	84.5	104.1	112.1
June	82.0	98.6	106.0	84.0	103.9	111.6
July	83.0	98.6	107.0	85.0	105.5	113.2
August	84.5	101.2	108.5	86.5	107.1	114.9

[a]London prices were used as Toronto producer prices were not available for 1972.
[b]Retail prices were not available for 1972.
[c]Quebec City prices were used as Montreal producer prices were not available in 1972.

Source: Agriculture Canada, *Poultry Market Review.*

provincial figure is weighted by its allocated share of national production.[16] A producer return is added to the national weighted average cost. The Ontario producer price is set equal to the national weighted average cost. That price is reduced by a Toronto-Winnipeg per dozen transportation charge to yield a base price in Manitoba. To this, transportation and handling charges from Manitoba to other provinces are added to develop provincial prices for Grade A large eggs. Manitoba was chosen as a base point price because it has historically been the lowest cost province and the source of much interprovincial trade in eggs. Base pricing out of Manitoba therefore facilitated trade for that province. Prices for Prince Edward Island and Newfoundland are calculated using the Nova Scotia price as a base.

Prices for other sizes are generally set in relation to Grade A large. Although the other prices are usually set in consultation with CEMA, provincial boards can determine them on their own.

The Surplus Removal Program

When a supply management system for eggs was established in Canada, CEMA accepted the obligation to ensure that egg production would be sufficient to accommodate the table egg market as well as the egg processors. Historically, the egg processing industry was the residual user of eggs, using either undergrades or table egg surpluses.[17] Processors usually bought during times of surplus but slowed processing during egg shortages, depending on seasonal or cyclical production patterns and to some extent, varying demand. Both table egg and processors' average requirements were in this way reflected in the 5-year production base used

[16] Statistics Canada determines each province's percentage share of the national market from the 5-year (1967-71) average of shares of total Canadian egg production.

[17] Grades B and C are generally not sold to the table market.

TABLE 6. PRICE LEVELS AND PRICE SPREADS OF GRADE A LARGE EGGS FOR TORONTO AND MONTREAL

	Producer Price	Producer-to-Wholesale Price Spread	Wholesale Price	Wholesale-to-Retail Price Spread	Retail Price
			¢/doz		
Toronto					
1971	–	–	38.8	–	–
1972	–	–	45.6	–	–
1973	–	–	70.1	–	–
1974	61.7	12.5	74.2	7.8	82.0
1975	60.8	13.2	74.0	8.1	82.1
1976	70.3	13.9	84.2	3.2	87.4
1977	70.7	15.4	86.1	0.1	86.2
1978	71.1	15.9	87.0	1.0	88.0
1979	77.7	16.0	93.7	2.5	96.2
1980	84.9	16.5	101.4	0.0	101.4
1981	96.9	17.7	114.6	9.7	124.3
Montreal					
1971	–	–	48.0	–	–
1972	–	–	47.7	–	–
1973	59.7	12.7	72.4	–	–
1974	64.0	13.9	77.9	5.5	83.4
1975	62.5	15.3	77.8	5.9	83.7
1976	70.6	14.6	85.2	8.2	93.4
1977	73.7	17.3	91.0	4.1	95.1
1978	73.6	18.5	92.1	4.9	97.0
1979	79.3	19.6	98.9	4.5	103.4
1980	86.9	21.0	107.9	-0.4	107.5
1981	98.9	23.5	122.4	4.0	126.4

Source: Agriculture Canada, *Poultry Market Review.*

to establish provincial quota allotments. The primary source of breaking stock is the volume of eggs surplus to the table market. CEMA removes the surplus Grade A product and offers it to the breaking trade at a formula price lower than the producer price. (To ensure that the lower-priced eggs do not resurface on the table market the shells are stained with dye.) The subsidy to egg processors is financed through a component in the cost-of-production pricing formula for table eggs equal to 2.5 ¢/doz. The subsidy was initially instituted because of an historically discounted price to egg processors.

The subsidy level in mid-1981 can support removal of about 38 500 boxes (of 15 doz) per week through the 2.7 ¢/doz consumer-subsidy-to-processors component in the table egg pricing formula. When surplus exceeds that amount, producers bear the additional costs in the form of special producer levies. During 1981, the producer levy at times reached 3 ¢/doz.

Ontario and Quebec Quota Allocations

Provincial quota shares were based on the 1967-71 5-year average production for each province. In 1981 the production base was still below that 5-year average since egg consumption had decreased during the past 10 years. The base period established Ontario as a surplus-producing province and Quebec as a deficit-producing province. It is difficult to estimate the exact extent of the surplus and deficit in each province because provincial consumption estimates are unavailable. If national, average per capita consumption is assumed for each province (which probably overstates Quebec's consumption), Quebec would have about a 51% production deficit in relation to its estimated consumption, Ontario producers an 11% surplus. These estimates, unfortunately, are based on figures which never find unanimous approval.

Price Patterns

Before the implementation of supply management, inelastic demand and cyclical supply created volatile production and egg prices. The supply management program sought to establish producer prices at a level which would cover production costs and a reasonable rate of return. The absence of a central decision-making authority often led to over-production, high imports and low exports coupled with low prices.

TABLE 7. NUMBER OF REGISTERED EGG GRADING STATIONS AND TOTAL THROUGHPUT, 1975 AND 1979

	Ontario		Quebec	
Year	No. of Stations	Total Throughput Boxes of 15 Dozen Eggs	No. of Stations	Total Throughput Boxes of 15 Dozen Eggs
1975	145	9 451 000	111	3 728 000
1979	88	10 375 000	106	3 643 000

Source: Marketing Services Division, Marketing and Economics Branch, Agriculture Canada.

After the inception of CEMA, egg price fluctuations became less volatile. Table 5, for example, shows various price levels during the 1971-72 (September-August) crop year, a period of stable feedstuff prices. Egg price volatility was more a result of egg supply volatility than feed cost volatility, compared with the corresponding period during the 1979-80 crop year, a year of rising feed costs. The producer price fluctuations in 1979-80 are more related to current production cost changes than to egg supply volatility.

Table 6 compares average yearly producer, wholesale and retail price levels for Montreal and Toronto. Montreal had higher prices at all three market levels from 1974 to 1981. Montreal also showed higher producer-to-wholesale price spreads for the period and higher wholesale-to-retail price spreads since 1976.

The higher producer prices in Montreal since 1975 can be explained by the difference between Toronto and Montreal transportation charges from Manitoba. Table 4 shows freight charges from Manitoba to Montreal to be 2.0 ¢/doz higher than to Toronto. Differences in wholesale prices are probably related to different industry structure in the two provinces.

STRUCTURE

Market Size

It is natural that the egg distribution system is organized around population centers. Eastern Ontario producers supply part of the Montreal and Ottawa-Hull markets. The Montreal market accounts for nearly 45% of Quebec's total consumption.[18] The larger wholesale marketers in eastern Ontario own their own grading facilities along with production quota for a substantial proportion of their egg station throughput. Their size allows them to easily supply a large retail chain with the chain's total requirements.

Within the framework of an agreement reached between FEDCO and retail buyers in Quebec, the latter agree to purchase no more than 45% of their egg requirements from outside the province. The remaining 55% must be bought in Quebec.

Number of Sellers and Relative Size

Table 7 gives the number of registered egg grading stations in Ontario and Quebec for 1975 and 1979. In 1975 there were 145 stations in Ontario with an average throughput of 65 thousand boxes a year.[19] The 111 Quebec stations processed an average of 34 thousand boxes. By 1979, Ontario had 88 stations with 118 thousand boxes, compared with 106 stations in Quebec with an average of still 34 thousand boxes. During this 4-year period, Quebec's throughput fell further behind that of Ontario. Simple averages, however, only provide one structural indicator and several other factors must be taken into consideration before one has a true picture.

The percentages of egg gradings produced by the four largest egg grading stations in the two provinces are shown in Table 8.[20] In 1975 the four largest stations in Ontario and the four largest in Quebec controlled 32% of the throughput. By 1979 the four largest stations in Ontario controlled 43% of the throughput in that province while the four largest stations in Quebec accounted for 36% of that province's. More significantly, perhaps, the average size of the four largest stations in Ontario in 1979 was 1130 thousand boxes a year, compared with 292 thousand boxes for Quebec.

Table 9 gives proxies for minimum efficient scale of production (MES) developed by Comanor and Wilson and Weiss.[21] Comanor and Wilson's proxy for MES is the average plant size among the largest plants account-

[18] *Évaluation des opérations de mise en marché des oeufs au Québec,* Drouin Paquin et Associés Limités, mars 1976.

[19] A registered egg grading station can include an independent grader, a producer-grader and even a packer. This study did not permit a detailed breakdown of the number of "firms" within each of these three categories.

[20] For analytical purposes it is more appropriate to treat each FEDCO plant as a separate firm rather than treat the sum of all grading stations under FEDCO control as one firm. This is particularly true in economy of scale measures.

[21] Stephen Davies, "Minimum Efficient Size and Seller Concentration – An Empirical Problem," *Journal of Industrial Economics*, March 1980.

TABLE 8. FOUR-FIRM CONCENTRATION RATIOS IN THE EGG GRADING INDUSTRY

Year	Ontario	Quebec
	percent of egg gradings produced by the largest four egg grading stations	
1975	32	32[a]
1979	43	36[a]

[a]The top four firms were FEDCO-controlled stations.

Source: Marketing Services Division, Marketing and Economics Branch, Agriculture Canada.

TABLE 9. PROXIES FOR MINIMUM EFFICIENT SCALE OF PLANT OF EGG STATIONS

Area and Year	Comanor and Wilson	Weiss
	— boxes of 15 dozen —	
Ontario		
1975	481 000	346 000
1979	1 000 000	479 000
Quebec		
1975	304 000	229 000
1979	276 000	178 000

Source: Marketing Services Division, Marketing and Economics Branch, Agriculture Canada.

ing for 50% of the industry's throughput, whereas Weiss's proxy is the size of the plant at the median of the output size distribution (i.e., 50% of industry output is accounted for by plants in excess of the median). Under the Comanor-Wilson measure, the MES in Ontario increased from 481 thousand boxes to 1 million between 1975 and 1979. Quebec's MES decreased during the same period from 304 thousand to 276 thousand boxes. According to this measure, Ontario shows larger minimum efficient scale of operation over time. The Weiss measure of MES shows a similar trend, although the estimated sizes of the MES are different than those measured by Comanor-Wilson.

We may question, however, whether the Quebec measure of MES is a minimum efficient scale at all. Since FEDCO has a large measure of control over pricing of grading station throughput under one system, Quebec plant size has not been subject to the same economically competitive environment as that affecting grading stations in Ontario. In fact, a report on the situation of the poultry industry in Quebec reveals that the majority of FEDCO-controlled stations are underutilized. In the late 1970s, most of these stations were operating at only 60% of capacity.[22]

Taken together, Tables 7-9 demonstrate a trend toward increased consolidation and larger plant scale in Ontario throughout the 1970s. In Quebec, increased concentration did not occur during this period. In 1981, however, the second and fourth largest FEDCO plants in the province merged, thus contributing to increased concentration in the province. Since 1980, two other FEDCO stations have folded. Although the proportion of gradings controlled by the four largest Ontario graders might now be similar to that of Quebec, plant scale is still much larger in Ontario. Ontario has witnessed a gradual decline in the number of grading stations, whereas Quebec has had a loss in the number of FEDCO-controlled stations but an increase in the number of producer-graders. The throughput of the remaining FEDCO-controlled stations, however, has remained stable from 1975 to 1981.[23]

Number of Buyers

The major egg buyers are the retail chains. The Toronto market appears to be more competitive than Montreal's at the retail level, with Dominion, Loblaws, Miracle Food Mart, A & P, Safeway and the Oshawa group being well represented. Montreal has long been controlled by two major chains: Steinberg and Dominion (Provigo recently bought Dominion's interests in Montreal). Although current statistics are unavailable, evidence shows that in 1976, half of FEDCO's total sales were in the Montreal market.[24]

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[22] *État de la situation, op. cit.*, p. 38.

[23] Food Production and Inspection Branch, Agriculture Canada.

[24] Drouin, Paquin et Associé, Limitée, *op. cit.*

In Quebec, wholesale egg prices are established through negotiations between FEDCO and wholesalers. Thus Quebec's grading stations have more market power than those in Ontario where wholesale prices are not negotiated by a grading station association. Independent stations in Quebec usually follow FEDCO's wholesale price leadership.

CONDUCT

Pricing

Although the pricing formula discussed earlier allows a producer return, some producers argue that they are squeezed between what the formula price allows them to receive in their respective provinces and what they actually have to disburse in operational costs. Traditionally, Quebec producers have argued that they must pay higher feed costs and that, despite the formula pricing, their actual returns are lower than their Manitoba or Ontario counterparts.

It seems that the Ontario Egg Producers Marketing Board has accepted the principle that because the province's eastern producers pay more for feed, they should receive a higher price. They have divided the province into price zones where the minimum producer prices in the eastern counties are higher than those in the rest of the province.[25] Unlike Ontario, Quebec has only one producer price zone across the province.

Quebec producers pay a higher administrative fee for their marketing board's operations than their Ontario couterparts. There is a 2.5 ¢/doz administration levy provided in the CEMA cost of production formula which is passed on to consumers. But Quebec producers pay an extra cent to FEDCO. Some Quebec producers also complain that FEDCO stations typically grade a higher percentage of undergrade eggs than in Ontario where competition among independent egg graders often leads to pencil grading (payment for a higher grade-out than actually exists). FEDCO receives higher administrative margins partly because their mandate includes both grading and marketing activities.

At the wholesale level the Quebec legislation allows FEDCO to operate a wholesale price committee representing both the retail sector and FEDCO. This means that the price mechanism does not allow individual chains to negotiate a price on an individual basis (as in Ontario). They are, however, represented at the wholesale price committee. The fact that the wholesale price is uniform across the province means that FEDCO must sell in the smaller peripheral markets at the same price as the one for Montreal. The additional transportation costs within these markets are spread out across all markets. Compared with local producer-graders, this results in a lower cost-price performance for FEDCO stations.

Wholesale prices in Ontario are not regulated. Conversations with egg graders have indicated that the wholesale list price is a function of overhead costs, depreciation, labor, fuel and electricity, packaging, delivery and profit. The delivered price is a function of distance (transportation costs) and delivery size (volume discount).

In both provinces the marketing board ensures surplus removal but CEMA and the provincial boards set the intervention price. CEMA will buy back surplus eggs (Grade A, loose packed) at the producer prices plus 11¢/doz. The grading stations complain that this cost does not fully cover all their operational costs for grading a dozen eggs. CEMA argues that if the intervention price covered all marketing costs, there would be little incentive left for egg graders to merchandise their products. Basically, CEMA does not intend to take over the egg graders' merchandising functions. The intervention price sets a floor price for wholesale loose product.

Barriers to Entry

Because of the production quota system under supply management, barriers to entry at the producer level are firmly entrenched. Quota value and provincial maximums on operation size are two obvious barriers. But there are also barriers in the grading industry. Scale economies in Ontario provide an entry barrier problem and help to explain the continuing consolidation of the Ontario grading industry. In Quebec, scale economies are also a problem given the consolidation of two FEDCO stations and the closure of two others. There are also institutional barriers, e.g., a producer who wishes to grade his own eggs must seek permission from the Régie des Marchés Agricoles.

Product Differentiation

The egg grading industry does not self-advertise. There is an element of product differentiation, however, performed by large graders who can support the volumes required for an A-1 grade egg program. Steinberg's pays a premium to some graders to provide its stores with a continuous supply of A-1 eggs.

These eggs are from young flocks, spray-oiled on the farm to preserve freshness and graded within 48 hours (in contrast with other gradings within 72 hours). Because of the special flock identification and faster turn-out required in meeting A-1 standards, only a large grading operation can generally accommodate such requirements.[26]

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[25] For the counties of Prince Edward, Hastings, Lennox, Addington, Frontenac and Leeds, minimum producer prices are one cent above the minimum price and in Renfrew, Lanark, Grenville, Carleton, Dundas, Russell, Stormont, Prescott and Glengarry counties, minimum producer prices are 1.5¢ above the minimum price.

[26] The Steinberg retailer chain, which holds one of the largest market shares in Quebec, has used the marketing of A-1 eggs as one of their identifying characteristics. The A-1 eggs require special flock identification and egg handling to meet A-1 grade standards. Generally only a large-scale plant can accommodate the more demanding standards to meet a large chain contract.

PERFORMANCE AND CONCLUSION

Performance is gauged on the basis of how well an industry fulfills its functions in relation to price and cost. The functions of the egg grading industry are to determine the size and quality of eggs so that the buyer is assured of a standardized, wholesome product; provide a mechanism for paying egg producers; and market the product to wholesalers, retailers and the HRI trade. There are several differences in grading industry performance between the two provinces.

Determinating Egg Size and Quality

Table 6 shows that producer prices in Montreal averaged 1.9¢/doz more than those in Toronto during the 1974-81 period. But the producer return in Quebec is one cent less since FEDCO extracts an extra marketing levy. The true producer price differential between the two areas is 0.9¢/doz. Montreal wholesale prices during the same period averaged 4.8¢/doz more than those in Toronto. The approximately 2.8¢/doz wider producer-to-wholesale margin in Montreal indicates the higher cost structure in Quebec grading, relative to that of Ontario. Part of the higher cost may be attributable to FEDCO administration and part to marketing ability.

Quebec producers have also maintained that the grade-out they get is lower than that received in Ontario because FEDCO's position precludes any strong competition in terms of pencil grading. To the extent that these allegations are true, Quebec does perform a better job of accurate grading than Ontario.

Providing a Payment Mechanism for Producers

The 1¢/doz producer levy imposed by FEDCO implies a lower return to Quebec producers than to their Ontario counterparts as measured by the CEMA cost of production. In addition, the absence of pencil grading in Quebec implies lower producer returns on that basis as well. Competition among graders in Ontario, which leads to pencil grading, implies that producers, rather than graders, accrue the economic rents of supply management; whereas in Quebec, the rents are shared between producers and FEDCO. But FEDCO was set up to preserve the family farm, counterbalance the market power held by large retailers and generally improve the quality of the egg grading activity in Quebec. It appears that these objectives have been met, but at a cost of lost efficiency. The closure of two FEDCO-controlled stations and the remaining eight stations operating at 60% of capacity speak for themselves.

Marketing the Product

The smaller plant scale for grading in Quebec means that the Steinberg chain would tend to obtain their A-1 eggs in Ontario, where larger throughput can accomodate a continuous supply. In this case the A-1 program discriminates against smaller plants.

In Quebec, the presence of a wholesale price committee does not allow individual chains to negotiate a price on an individual basis (as in Ontario). A uniform price across the province means that FEDCO must sell its eggs in peripheral markets at the same price as the one for Montreal. Additional transportation costs being spread out across all markets results in a lower cost-price performance for FEDCO stations.

Comparative Advantage

Ordinarily, a situation of lower wholesale price in Ontario would imply product movement from Ontario into Quebec if the difference in price exceeded transportation costs. Provincial quota allocations, over the initial base, however, are based to a significant extent on comparative advantage. To the extent that this occurs, FEDCO's performance in wholesaling eggs, relative to that of Ontario or Manitoba has a direct and continuing impact on provincial quota shares.

The Quebec agreement limiting the retailer's access to out-of-province eggs to 45% of requirements and FEDCO's ability to set the wholesale price may have limited competition within Quebec. Such protection has allowed producer-graders to develop under an umbrella price structure determined by FEDCO.

Such a situation is usually seen as being economically inefficient. However, the population distribution in Quebec is much different from the one in Ontario. Nearly 40% of Quebec's population resides in the Montreal area, whereas most of its producers are in outlying areas. The nature of the business calls for inflexible arrangements between the grader and the retailer. FEDCO felt that without protection, the consumers in outlying areas would not be provided with fresh eggs and the egg producers in those areas would not be able to find a market. As a result, the larger Montreal retailers have found it easier to buy large shipments from the integrated egg graders in Ontario.

Estimating production costs and returns for Atlantic raspberries

Total measurable costs ranged from $6892 to $7572/ha annually for pick-your-own raspberry sales and from $10 542 to $14 611/ha annually for fresh market berries.

Net returns were extremely sensitive to yield and price fluctuations. The breakeven price for pick-your-own raspberry sales was $1.17/L at a 4200L/ha yield. Similarily, the breakeven price for fresh berry sales was $1.79/L at the same yield level.

A.C. Grant

INTRODUCTION

In the spring of 1981, the Advisory Committee on Economics, Extension and Education (ACEEE) requested current cost of production data that would be applicable to raspberry operations in Atlantic Canada. In response to that request, the Regional Development and International Affairs (RD&IA) Branch of Agriculture Canada in Truro, Nova Scotia, conducted a study aimed at estimating growing and harvesting costs for commercial raspberry enterprises in the region. This paper summarizes the results of that study which are found in the publication "Estimating Production Costs and Returns for Atlantic Raspberries" (November 1981).

The raspberry enterprise model used as a basis for the study was designed to be fairly representative of a typical commercial raspberry operation in Atlantic Canada. Production costs were estimated for each of the establishment years in addition to the computations of production and harvesting costs for the crop years. Returns were calculated using varying yield levels and their respective costs over a range of market prices.

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The data contained within the report provide useful information that serves as a guide to potential commercial raspberry growers in the region. The information may also be used as a management tool in assessing raspberries as part of the total farm operation. Moreover, the approach allows for a degree of flexibility that accounts for a wide range of conditions, production practices, management capabilities and market prices.

INDUSTRY BACKGROUND

Atlantic Canada's raspberry industry is of minor importance in terms of its contribution to the total farm value of small fruit production. In 1979, raspberry production in the Maritime Provinces (figures for Newfoundland are unavailable) had an estimated farm value of $101 000, about 1% of the total farm value of the region's small fruit production. Production has remained fairly stable during the past 10-15 years, showing less than a 10% increase since 1971.[1] The industry is dominated by a large number of small volume producers. Although there are approximately 10-15 semi-commercial growers in the region, the smaller, backyard operations predominate.

There appears, however, to be a significant opportunity for expanded raspberry production in Atlantic Canada. Aside from the relatively unexploited market for fresh berries at the wholesale and retail levels, the recent rise in popularity of pick-your-own operations has dramatically increased the crop's marketing potential. In 1979, production of the crop in the three Maritime Provinces accounted for less than 15% of the total estimated consumption (based on a national per capita consumption of 0.20 kg). Furthermore, opportunites exist for raspberries grown for processing. Some firms in the region have expressed an interest in obtaining local production.

In the past, however, there has been reluctance among the region's raspberry producers to enter into large-scale, commercial production. Low yields and fluctuating winter conditions, often causing severe cane damage, coupled with the fruit's perishability and poor shipping ability have greatly limited the crop's commercial success in Atlantic Canada.

A substantial amount of research has been done during the past several years to try to remove the varietal constraint, which seems to be the major growth restriction facing the industry. In 1963, for example, a new virus-free-stock program was initiated which was one step towards providing the region with clean raspberry

[1] Statistics Canada, Truro.

TABLE 1. RASPBERRY ENTERPRISE MODEL (2 ha on a 40-ha farm) CROPPING PLAN

Year	Spring	Summer	Fall
Fallow year	Spray with Roundup Plow once Disk once Harrow once Lime	Harrow twice	Harrow once
Planting year	Fertilize (0-20-20) Disk once Harrow once Plant canes Cultivate twice	Cultivate twice Spray with herbicide Hand hoe as weeds persist	
Training year	Replace winter killed canes (5%) Fertilize (17-17-17) Cultivate once Apply fungicides Erect training wires and posts	Irrigate Apply 3 applications of chemicals for weeds and disease	Prune trellis
Crop years (8-10 years)	Thin canes (weak, diseased and winter killed)	Apply herbicide Apply chemicals 5 times for insects and disease Harvest (July—August)	Prune trellis

stock. There have also, since 1964, been many variety breeding programs underway throughout the Maritimes.

Research results are promising and in view of the opportunities available, industry specialists believe that larger, commercial raspberry plantings could be advocated in the near future. Grower interest in the crop is extremely high and some producers consider raspberry production a viable addition to their farm structure.

METHODOLOGY

In terms of its size and structure and the available opportunities, Atlantic Canada's raspberry industry is in its infancy. For this reason the actual cost data obtained from the region's growers could not be used for estimating commercial production costs. To determine the various costs involved a consensus approach was taken, obtaining recommendations from horticulturists, researchers and extension personnel involved in the raspberry and related industries. In addition, a significant portion of the information received from the region's larger, semi-commercial growers was used to evaluate current cropping and management techniques.

This information was used to develop a commercial raspberry enterprise model that was best suited to the Atlantic climate (Table 1). The methodology involved simulating the process of growing and harvesting raspberries commercially from the initial fallow year through to the final crop year.

The duration of the rotation outlined in Table 1 will vary, depending upon, among other factors, the persistance of disease and weed problems prevalent in the raspberry planting. However, assuming an initial 3 years for establishment, with adequate crop husbandry the planting should remain profitable for at least 8-10 years.

It is recommended that the initial year of operation be a fallow year, to eradicate weeds and provide suitable field conditions for planting in the second year. Following the planting year, the canes are trained with the linear training system, a modification of the more traditional hedgerow system. The planting distances are the same, but with the linear system the suckers or clones are not allowed to fill the row; instead, groups of 5-8 suckers are kept at the point of the original planting.

This linear training system is the most suitable for Atlantic growing conditions. While requiring more labor to maintain than the traditional hedgerow, the linear system provides better weed, insect and disease control.

During the spring of the training year it is recommended that a spread trellis system be erected, consisting of posts and cross-pieces supporting one or two strands of galvanized wire. This provides support, protects the planting from cane breakage and facilitates harvesting.

TABLE 2. ESTIMATED COSTS FOR THE FALLOW YEAR

Expense Category	Material	Labor	Tractor	Machinery	Other	Total
			$/ha			
Plowing	–	20.38	36.12	36.10	–	92.60
Discing	–	6.79	12.05	25.25	–	61.94
Harrowing	–	17.93	31.80	20.50	–	70.23
Liming (custom)	76.84	–	–	–	–	76.84
Spraying	106.25	3.41	6.02	5.97	–	121.65
Interest (materials)	–	–	–	–	10.99	10.99
Land rental	–	–	–	–	173.00	173.00
Miscellaneous	–	–	–	–	61.77	61.77
Growing costs	183.09	48.51	85.99	87.82	245.76	651.17

Yields will vary (and probably decline) from one year to the next, depending upon the planting's stage of production. However, it was assumed that the costs of production and harvesting in each of the 10 crop years to be constant, since it was difficult to measure any changes from year to year without technical data. And since only a small percentage of the actual yield was produced in the third year, it was assumed that commercial harvesting did not occur until the fourth year.

Incorporated into the model are two types of harvesting method – the traditional one of harvesting berries using paid labor and the more popular pick-your-own method. Again, data were not available to suggest any yield differences between the two methods; therefore, three yield levels were assumed and their respective costs for each harvesting method.

All yield levels used in the calculations of harvesting costs and per hectare returns reflect an estimation of the actual yield harvested. Therefore, allowances have been made for crop losses caused by insect and disease damage, etc.

All costs in the study were estimated based on a 2-ha raspberry enterprise on a 40-ha farm. It was assumed that all the necessary general farm equipment (tractors, sprayers, etc.) used in the raspberry operation was available from the other enterprises. Operating charges were based on the cost of renting the equipment from competing enterprises. This calculated rental charge illustrated the opportunity cost of using that equipment in raspberry production. The rental cost was based on an hourly charge for depreciation, repairs and interest.

All specialized equipment used solely for raspberry production was charged into the operation at its capital cost. Operating costs calculated were for this specialized equipment on an hourly charge for repairs and interest.

Labor charges were based on a rate of $5.50/h for unskilled, seasonal labor. Material costs were obtained from a survey of input supply firms throughout the Atlantic region. The hours per hectare for the cropping activities involving machinery reflect the average time requirements for small fields using small equipment.

The first 3 years of operation (the fallow, planting and training years) are treated as establishment years since no production occurs during that period. Establishment costs are thus accumulated until they can be repaid from berry sales.

We see these costs as increasing the asset value of the land; therefore, by amortizing the accumulated establishment costs, this added value can be depreciated over the planting's productive lifetime. Amortization proportions the repayments of these costs equally over the harvesting years. This was necessary since crop years were assumed to be constant in terms of production and harvesting costs.

ESTIMATED COSTS OF PRODUCTION AND HARVESTING

The estimated costs for the various cropping activities occurring within each of the 13 years are included under five major expense categories: materials, labor, tractor, machinery and other costs. Other costs include charges for trucking raspberry canes and fertilizer, interest on materials, cost of renting land and miscellaneous expenses.

Interest was calculated on materials at 18% over a 4-month period. Land for raspberry production was rented from the total farm enterprise at $173/ha. Miscellaneous expenses covered costs for telephone, hydro and small tools.

Table 2 shows that the total estimated costs incurred in the fallow year were $651.17/ha. This includes $183/ha for materials (lime and sprays), $48 for labor, $86 for tractor operating costs, $88 for machinery and $246 for other costs.

TABLE 3. ESTIMATED COSTS FOR THE PLANTING YEAR

Expense Category	Material	Labor	Tractor	Machinery	Other	Total
			$/ha			
Discing	–	6.79	12.05	25.85	–	44.09
Harrowing	–	4.52	7.95	5.13	–	17.60
Planting	1210.93	191.75	–	–	77.06	1439.74
Cultivating	–	40.77	72.27	189.55	–	302.59
Fertilizing	317.52	18.48	6.02	7.06	7.41	356.49
Interest (materials)	–	–	–	–	91.70	91.70
Land rental	–	–	–	–	173.00	173.00
Miscellaneous	–	–	–	–	61.77	61.77
Growing costs	1528.45	262.31	98.29	226.99	370.94	2486.98

TABLE 4. ESTIMATED COSTS FOR THE TRAINING YEAR

Expense Category	Material	Labor	Tractor	Machinery	Other	Total
			$/ha			
Planting	37.06	69.43	–	–	12.35	118.84
Cultivating	–	10.18	18.06	47.39	–	75.63
Irrigating	2965.25	176.70	–	471.69	–	3613.64
Fertilizing	374.36	18.48	6.02	7.06	7.41	413.33
Spraying	114.21	13.59	24.09	23.96	–	175.85
Trellis support	1362.92	353.35	120.46	17.54	–	1854.27
Pruning	–	489.26	72.27	10.52	–	572.05
Interest (materials)	–	–	–	–	291.23	291.23
Land rental	–	–	–	–	173.00	173.00
Miscellaneous	–	–	–	–	98.84	98.84
Growing costs	4853.80	1130.99	240.90	578.16	582.83	7386.68

In the second year, planting charges, which includes the costs for raspberry cane material, labor and transportation, accounted for more than 57% of the total per hectare costs. No machinery costs were attributed to the planting activity since it was assumed that the canes were planted entirely by hand. As indicated in Table 3, total estimated growing costs in the planting year were $2487/ha. Material costs were $1528/ha, labor $262, tractor $98, machinery $227 and other costs $371.

Table 4 illustrates the estimated growing costs for the training year. Material costs in the third year accounted for approximately 65% of the total per hectare costs. Trickle irrigation equipment was valued at $2965/ha. Labor and equipment costs associated with irrigating included the time required for field set up, etc., in addition to the per hour operating costs. Material costs for the trellis were $1363/ha, while labor and equipment costs included the costs of construction and maintenance. Total growing costs in the training year were $7396/ha, of which $4854 went for materials, $1131 for labor, $241 for tractor, $578 for machinery and $582 for other costs.

As previously mentioned, estimated per hectare growing costs for each of the 10 crop years were assumed to be constant, with the exception of the sixth crop year. Total estimated production costs for each of the crop years was $3496/ha (Table 5). In the sixth year the posts and cross pieces on the trellis were replaced at a cost of $1124/ha. Estimated growing costs in that year were $4620/ha. For all other crop years, material costs were $849/ha, labor $1449, tractor $253, machinery $590 and other costs $355.

TABLE 5. ESTIMATED COSTS FOR CROP YEARS 1 – 10[a]

Expense Category	Material	Labor	Tractor	Machinery	Other	Total
			$/ha			
Cultivating	–	10.18	18.06	47.39	–	75.63
Irrigating	–	95.13	–	471.69	–	566.82
Fertilizing	374.36	18.48	6.02	7.06	7.41	413.33
Spraying	475.03	20.38	36.12	35.95	–	567.48
Cane thinning	–	652.35	96.37	14.03	–	762.75
Pruning	–	652.35	96.37	14.03	–	762.75
Interest (materials)	–	–	–	–	50.95	50.95
Land rental	–	–	–	–	173.00	173.00
Miscellaneous	–	–	–	–	123.55	123.55
Growing costs	849.39	1448.87	252.94	590.15	354.91	3496.26

[a]In the sixth crop year the trellis support was replaced. Production costs in that year were $4620.

TABLE 6. HARVESTING COSTS FOR FRESH MARKET RASPBERRIES

Yield per Hectare	Material	Labor	Trucking	Total
		$/ha		
5 880 L	1245.05	2551.35	279.69	4085.09
8 820 L	1881.08	3825.17	432.33	6138.58
11 760 L	2508.10	5102.70	583.04	8193.84

TABLE 7. HARVESTING COSTS FOR PICK-YOUR-OWN RASPBERRIES

Yield per Hectare	Material	Labor	Trucking	Total
		$/ha		
5 880 L	–	434.90	–	434.90
8 820 L	–	788.26	–	788.26
11 760 L	–	1155.21	–	1155.21

The total estimated establishment costs from Tables 2, 3 and 4 were amortized over the remaining 10 years. The total compounded establishment costs (including interest) amounted to $13 512/ha. Amortization at 18% over 10 years gave a yearly payment of $2921/ha in each of the crop years.

HARVESTING COSTS

Total harvesting costs will vary according to the actual yield harvested and the harvesting system used. Harvesting costs for fresh market berries were significantly more than those for pick-your-own since they included the additional costs for boxes, crates, picking and trucking.

Labor charges for fresh market berries included the costs of picking and supervisory labor. Trucking charges included a charge for the driver's time in addition to a per kilometre cost of trucking boxes and crates from suppliers and transporting raspberries to market. Harvesting costs for pick-your-own enterprises were based solely on the amount of required supervisory labor.

Estimated yields of 5880, 8820 and 11 760 L/ha were used to calculate harvesting costs for the two alternatives. As indicated in Table 6, fresh market harvesting costs ranged from $4085 at the lower yield level to $8194 for the higher yield. Similarly, pick-your-own harvesting costs were spread between $435 and $1155/ha (Table 7).

TABLE 8. SUMMARY OF PRODUCTION AND HARVESTING COSTS

Yield	Fresh Market	Pick-Your-Own
	$	
5880 L		
Amortized establishment costs	2 921.00	2 921.00
Crop year production costs[a]	3 496.26	3 496.26
Harvesting costs	4 085.09	434.90
Total cost per hectare	10 542.35	6 892.16
8820 L		
Amortized establishment costs	2 921.00	2 921.00
Crop year production costs[a]	3 496.26	3 496.26
Harvesting costs	6 138.58	788.26
Total costs per hectare	12 555.84	7 205.52
11 760 L		
Amortized establishment costs	2 921.00	2 921.00
Crop year production costs[a]	3 496.26	3 496.26
Harvesting costs	8 193.84	1 155.21
Total costs per hectare	14 611.10	7 572.47

[a]Crop year production costs for year six are $ 4620.

SUMMARY OF COSTS

By incorporating three yield levels into the two harvesting systems, production and harvesting costs can be calculated for six possibilities. As previously indicated, the production costs for fresh and pick-your-own marketings are equal and assumed to be constant during the 10 harvesting years. Likewise, the amortized establishment cost is constant throughout the production period and is the same for the two harvesting alternatives and each yield level.

Total measurable costs ranged from $6892 to $7572/ha for pick-your-own raspberry sales. Costs for fresh market berries extended from $10 542 at the lower yield levels to $14 611/ha at the higher yield level (Table 8).

RECEIPTS, COSTS AND RETURNS

Tables 9 and 10 indicate the gross receipts, costs and net returns per hectare, calculated for the two harvesting methods over a range of market prices and each of the three yield levels. This approach illustrated how sensitive net returns were to changes in yields and market prices.

Net returns for fresh berry sales were negative at the lower yield and market price combinations. The break-even price was at the lower yield level at a market price of approximately $1.79/L. Net returns increased quite significantly at higher market prices and yield combinations.

At the 8820 L/ha yield level, net returns ranged from $675/ha at a market price of $1.50/L to $8613/ha for a market price of $2.40/L. For the 11 760 L/ha yield, per hectare net returns extended from $3029 to $13 613/ha.

Net returns from pick-your-own sales showed similar results, using a $0.60/L lower market price calculated similarly. Net returns per hectare for both marketing alternatives represented the returns to management and investment since labor costs were included in the total production costs.

SUMMARY AND CONCLUSIONS

The data contained in this report are simply estimations of raspberry costs and returns based on available information. The information is intended to be a guide and management tool for commercial raspberry production, not a definitive survey of the industry in Atlantic Canada.

Our approach has some obvious limitations when estimating production costs, since it is based on a strictly defined set of assumptions. As with any agricultural enterprise, some factors cannot be accounted for with any acceptable degree of certainty. Therefore, while conclusions drawn from the results may indicate an attractive return on investment, the degree to which this is actually realized is dictated by such uncontrollable factors.

TABLE 9. SUMMARY OF RECEIPTS, COSTS AND RETURNS FOR A FRESH MARKET RASPBERRY ENTERPRISE[a]

Category	Yield per Hectare		
	5 880 L	8 820 L	11 760 L
		$/ha	
Gross receipts			
@ $1.50/L	8 820	13 230	17 640
@ $1.60/L	9 408	14 112	18 816
@ $1.70/L	9 996	14 994	19 992
@ $1.80/L	10 584	15 876	21 168
@ $1.90/L	11 172	16 758	22 344
@ $2.00/L	11 760	17 640	23 520
@ $2.10/L	12 348	18 522	24 696
@ $2.20/L	12 936	19 404	25 872
@ $2.30/L	13 524	20 286	27 084
@ $2.40/L	14 112	21 168	28 224
Total costs	10 542	12 555	14 611
Net returns			
@ $1.50/L	-1 722	675	3 029
@ $1.60/L	-1 134	1 557	4 205
@ $1.70/L	- 546	2 439	5 381
@ $1.80/L	42	3 321	6 557
@ $1.90/L	630	4 203	7 733
@ $2.00/L	1 218	5 085	8 909
@ $2.10/L	1 806	5 967	10 085
@ $2.20/L	2 394	6 849	11 261
@ $2.30/L	2 982	7 731	12 437
@ $2.40/L	3 570	8 613	13 613

[a]Net returns for all yield levels will decrease $1136/ha in crop year six, reflecting the added costs for replacing the raspberry trellis.

Our results suggest that the total cost of establishing a commercial raspberry operation in Atlantic Canada is $10 535/ha. Amortizing this amount and the appropriate interest charges incurred in the establishment years resulted in a yearly payment of $2921/ha in each of the remaining 10 years. Total estimated production costs for the crop years was approximately $3496/ha, except in crop year six when costs were estimated to be $4620/ha.

Harvesting costs were calculated for both fresh and pick-your-own marketing alternatives. Estimated yields of 5880, 8820 and 11 760 L/ha were used in calculating per hectare harvesting costs for each of the harvesting alternatives. Fresh marketing harvesting costs were significantly more than pick-your-own costs at respective yield levels since they included the additional costs for materials, labor and transportation.

Net returns for both harvesting methods were negative at the lower yield and price combinations. The break-even price was at the lower yield levels at a market price of $1.79/L for fresh market and $1.17/L for pick-your-own sales.

Returns increased quite significantly at higher yield and price combinations, illustrating how sensitive net returns were to changes in yields and prices. Based on the findings of this study and in view of the marketing potential that exists for the crop in Atlantic Canada, commercial raspberry production, assuming adequate management, should provide acceptable returns relative to similar crop enterprises in Atlantic Canada.

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TABLE 10. SUMMARY OF RECEIPTS, COSTS AND RETURNS FOR A PICK-YOUR-OWN RASPBERRY ENTERPRISE[a]

Category	Yield per Hectare		
	5 880 L	8 820 L	11 760 L
		$/ha	
Gross receipts			
@ $0.90/L	5 292	7 938	10 584
@ $1.00/L	5 880	8 820	11 760
@ $1.10/L	6 468	9 702	12 936
@ $1.20/L	7 056	10 584	14 112
@ $1.30/L	7 644	11 466	15 288
@ $1.40/L	8 232	12 348	16 464
@ $1.50/L	8 820	13 230	17 640
@ $1.60/L	9 408	14 112	18 816
@ $1.70/L	9 996	14 994	19 992
@ $1.80/L	10 584	15 876	21 168
Total costs	6 892	7 205	7 572
Net returns			
@ $0.90/L	-1 610	733	3 012
@ $1.00/L	-1 022	1 615	4 188
@ $1.10/L	- 434	2 497	5 364
@ $1.20/L	154	3 379	6 540
@ $1.30/L	742	4 261	7 716
@ $1.40/L	1 330	5 143	8 892
@ $1.50/L	1 918	6 125	10 068
@ $1.60/L	2 506	6 907	11 244
@ $1.70/L	3 094	7 789	12 420
@ $1.80/L	3 682	8 671	13 596

[a]Net returns for all yield levels will decrease $1136/ha in crop year six, reflecting the added costs for replacing the raspberry trellis.

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Sustainability in the Canadian agri-food system

Canada is witnessing a deterioration of soil resources, significant losses in its farmland base and a growing dependence on high energy technology. Although this country has excellent land research capability, preserving agricultural resources is still not a high enough national priority. The author recommends that (1) the findings of land resource research should be used in regional development planning, (2) on-farm and public awareness of issues related to land resource protection should be promoted and (3) funding programs should create incentives for on-farm use of sustainable production practices.

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INTRODUCTION

This paper examines the future of Canada's agricultural land base from a broad viewpoint. The long-term sustainability of present agri-food production practices are examined by reviewing and summarizing published articles and discussions. Since many land use issues are covered, conclusions reached by previous authors, rather than detailed statistical presentations are relied upon.

Changes in farming techniques have raised production efficiency and reduced the level of human involvement in the actual use of land and soil resources. For instance, less than 5% of the Canadian population is now involved in farming, but this country is still a net exporter of agricultural goods. The number of farmers across Canada dropped more than 11% since 1971, while investments in farm machinery increased four times during the same period. The substitution of human involvement with increased chemical inputs and mechanization has a wide range of environmental implications which are not yet completely understood.

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The demand for agricultural goods produced in Canada is still below our farmland's production potential. Therefore, there is little economic incentive to keep land in production in many parts of the country. At the same time, population growth has had the opposite effect, which is to cause farmland to be taken out of production to satisfy urban and industrial expansion pressure (Bray 1979). The highest pressure is in parts of Canada which have land most suited to intensive agriculture. Although the net farmland loss in Canada has been small (2.8% between 1956 and 1976), large losses have occurred in Ontario and Quebec with gains in the more northern parts of western Canada (Bray 1979 and Dumanski 1980). This new land is usually less productive.

BACKGROUND

The dangers facing our future food producing capability have been noted on many occasions. The growing dependence on energy and capital intensive technology and the reduction of the land base raise questions concerning the sustainability of Canada's food production system. The question of maintaining a sustainable level of food production has been the theme of several recent conferences and workshops in Canada and the United States. Sustainable Food Systems was the theme of the 1981 Agricultural Institue of Canada Conference. A recent issue of the Agrologist (Vol. 9, No. 4, 1981) was devoted to soil as a dwindling resource. In the United States, a national workshop to determine research priorities on soil and water resources was held at Madison, Wisconsin, in 1981 (Larson *et al.* 1981). And in Canada, Bentley (1981) has effectively carried the message of the vulnerability of our land resource base in a series of lectures given across the country. In fact, Bentley convincingly describes a land crisis looming in our future.

Just as problems in agricultural land use have been identified, so has the resource potential of the land been extensively studied. The first national assessment of land resources produced the Canada Land Inventory, through the Agricultural Rehabilitation and Development Act (Pratt 1965). This resulted in a series of reports and maps and an index which classifies land according to its agricultural capability (1 to 7). The work involved agronomists, soil scientists, climatologists and geographers.

Land resource research has continued since the first national assessment, in the form of soil surveys, climatic assessment, land use and evaluation studies and land degradation analyses. Research techniques for studying land have also improved considerably. At Agriculture Canada the Research Branch has brought together these efforts through the creation of the Land Resource Research Institute, based in Ottawa.

At Environment Canada the Lands Directorate has also done extensive land assessment, although from a broader perspective than just agriculture. Many provincial governments have also established agencies to assess environmental issues. Land resource research is also carried out in many Canadian universities.

Canada, therefore, has considerable expertise in land resource study, land use and associated land degradation problems. Our research in this area compares favorably with that of any country.

What is missing, however, is an adequate level of awareness of the results of land resource research and economic incentives to make safeguarding our agricultural land base a high priority.

Since the responsibility for land legislation lies with the provincial governments (Bray 1979), the possibility for developing a national land preservation policy is limited (Buckley *et al.* 1980). Many provinces pass this responsibility on to regional and municipal governments (Runka 1980).

Dependence on high energy technology in agriculture is growing. This technology is capital intensive. It forces farmers into large debts and limits their options for long-term land resource management. The large capital investment required to own and operate a farm forces many farmers to leave farming (Buckley *et al.* 1980) or to maximize yields through capital intensive practices, often disregarding the long-term damage to their land. Under these conditions it is doubtful whether today's food production level can be sustained or if the potential for increasing food production will exist if current trends continue.

THE SUSTAINABILITY CONCEPT

Sustainability refers to the state of agricultural production in which the supply of required inputs can be maintained indefinitely at their current levels and the depletion of renewable resources is not progressing at a faster rate than the rate of renewal.

This definition is consistant with the concept of sustainable food systems, designated as the theme of the Agricultural Institute of Canada's 1981 conference.

A self-sustaining agri-food system does not mean a closed system which requires no external non-renewable resources, particularly at the farm level. Such a philosophy would mean a return to the workhorse era and a drastic reduction in production. The concept deals primarily with the use and management of renewable resources. If sustainability is not adapted as a guideline for future development, our land base resource will be seriously reduced within the next decade and opportunities for expanding agricultural production will be lost.

CURRENT UNSUSTAINABLE PRACTICES

To better understand what sustainable production means it is helpful to look at examples of resources which should be renewable. These include production practices which have or will lead to degradation of our land and soil resources, e.g., land taken permanently out of production and topsoil erosion and deterioration.

Soil Erosion

Soil erosion reached a crisis during the dust bowl era in the 1930s, affecting the prairies in both Canada and the United States. This resulted from a combination of dry weather which persisted for several years and farming practices which did not take into account the risk of blowing topsoil (Anderson *et al.* 1966). As a result of that experience, western farmers learned to plant trees as windbreaks, to use strip cropping to reduce the width or wind-run across fallow fields and to keep tillage operations which left fields without a crop cover to a minimum. Many farmers today, however, have apparently forgotten these lessons (Runka 1980). For instance, windbreaks and strip cropping have been abandoned to facilitate more efficient use of large machinery. Wind erosion is now a major cause of nutrient loss, particularly nitrogen, in western Canada (Campbell and Biederbeck 1980).

Although soil erosion by water was recognized as a serious problem several decades ago (Garland 1961 and Ripley *et al.* 1969), it is still a serious problem in many areas. The problem is apparent throughout eastern Canada, particularly where hillsides with silty loam textured soils are farmed. Planting annual crops with rows running down the slope rather than across is one such practice. Fall plowing, which leaves the ground without effective cover, is another. Annual crops, which deplete organic matter as well as nutrients, lead to soil structure deteriroration (Coote 1980 and Runka 1980). Zero or minimum tillage offers an alternative but requires large applications of chemicals, whose long-term effects still require research (Saskatchewan Tillage Committee 1981 and Campbell and Biederbeck 1980).

Soil Salinization

Of equal concern today in western Canada is the spread of soil salinization. This problem arises from the build-up of salt ions, particularly sodium, near the soil surface in certain arid regions. This salt accumulation promotes the breakdown of soil structure and interferes with root absorption of water and nutrients (McKenzie *et al.* 1981). Although large areas in Saskatchewan and Alberta are naturally saline, the problem is aggravated by irrigation and over-use of summer fallowing to build up moisture reserves on certain soils (Cairns *et al.* 1977).

Monoculture farming

Monoculture farming (the continous growing of one crop) is also an unsustainable system. Its first effect is the inevitable build-up of pest populations. And pesticide control can lead to residue accumulation (Agriculture Canada 1973). Nitrogen and organic matter are often depleted as well, thus requiring increased fertilizer use. Corn is a good example of this. Potato production in the Upper St. John River Valley illustrates both the dangers of cultivating erosion-prone hillsides and of monocultures (Saini and Grant 1980).

Grazing and Pasturing

Poor management of livestock grazing land and pasture is another unsustainable practice. Overgrazing, the result of overstocking livestock on pasture land, leads to the replacement of desirable forage species, either native or cultivated, by weed species. In a semiarid climate, such as southwestern Saskatchewan, overgrazing is most apparent when herd sizes are allowed to expand without considering what the carrying capacity would be in drought years and without reducing herd sizes during these years. There are considerable differences in drought risk on pasture land within each of the Prairie Provinces, as illustrated in a recent climatic analysis by Dyer (1982). Lodge and Campbell (1971) have shown regional differences in carrying capacity throughout the prairies.

Soil Compaction

Tillage can also lead to soil deterioration through compaction. The long-term effects of soil compaction in Canada are not as great as those in southern climates because of the depth of frost penetration. Miller (1981) and Raghavan *et al.* (1978), however, have documented certain short-term impacts. These include erosion due to increased surface runoff, decreased root penetration and aeration of topsoil.

Heavy Traffic

Heavy machinery traffic on wet, high clay fraction soils can destroy soil structure. The impact can be reduced by scheduling field work to coincide with days when fields are sufficiently dry (Moore *et al.* 1979). Two national studies have been carried out on the probabilities of workdays (Dyer *et al.* 1979 and Dyer 1980) to help farmers choose the type and size of machinery needed for scheduling field work and completing spring planting and fall harvesting on time. In many cases such field work scheduling is still not being done. There are two reasons for this. First, some farmers are reluctant to invest in machinery large enough to complete field work in the required time (Dyer *et al.* 1978). Second, other farmers are unaware of the importance of scheduling field work according to weather conditions.

Loss of Prime Land

Probably the most important consideration in maintaining a sustainable food production system is the loss of prime agricultural land. Although we live in the second largest country in the world and have a relatively small population, land is still a limited resource. Only 13% of our total land area (including rough grazing land) is agriculturally useful (Dumanski 1980). Of this, only a small part in the most southerly regions, about 7% of the whole country (Bray 1979), can support a wide range of field crops.

It is a myth that as land with the warmest climates and best soils is lost to urban development the northern frontiers of agriculture can be expanded. Many northern regions have excellent soils, but the climate to support crop growth just isn't there (Williams 1975). The length of the growing season and the radiation and heat accumulated over that season pose real limits to many crops (Dubé 1981). The climatic limitations in many regions of Canada have been demonstrated in several mapping studies (Dumanski and Stewart 1981, Chapman and Brown 1966 and Agrometeorology Section 1976). Although new varieties and cropping techniques can be developed to adapt many crops to marginal land, yield expectations on Class 4 land are still only half that of Class 1 land, even with the full application of technology (Bentley 1981).

Economic Incentives

It is also a myth that our food production system will be safeguarded by increased economic value of farmland as demand for food increases. Crosson (1982), in an attempt to evaluate the loss of agricultural land from an economic viewpoint, concluded that there wasn't a land crisis in the United States now but prospects for one are good. His conclusions were supported by a gathering of soil scientists and agronomists concerned with land research programs (Larson *et al.* 1981). The loss of agricultural land to urban growth is irreversible and by the time that economic demands for food have raised food production incentives, the supply of top value land will have been lost. Some dramatic examples of prime agricultural land going out of production are in the Okanagan Valley in British Columbia, Southwestern Ontario and, most recently, the Calgary-Edmonton corridor in Alberta.

Nonrenewable Inputs

Another aspect of sustainability is the dependence on a continued supply of nonrenewable inputs (Bentley 1980). Fuels and farm chemicals, including pesticides and some fertilizers, are products of petroleum. And since the manufacturing of farm chemicals is dependent on energy, a constant energy supply is vital. The rising price of petroleum and its products will have an increasing influence on both the cost and supply of many current inputs. At the same time the dependence on them is growing. For the present, artificial fertilizers are still affordable. And as long as we can observe large yield increases with greater fertilizer applications on fields showing significant topsoil loss, it is difficult to appreciate the hazards of soil erosion.

Research Benefits

We should not assume that losses in our land and soil resources will be offset by research results. Bentley (1981) demonstrated that the rate of gains in yield levels due to research (i e., new crops, crop varieties and practices) has fallen off in recent years. In the future, more research will deal with higher energy costs and environmental protection, leaving less for further yield increases. There is growing opinion that crop breeding cannot raise yields in the most highly economic crops much more, since genetic potentials have already been reached. This is not yet true, however, for feed grains.

SOME SUSTAINABLE PRACTICES

Crop Rotation

Not all farming practices are unsustainable. Research has led to crop and soil management techniques which result in increased stability in soil structure and quality. For example, crop rotations provide an alternative to monocultures. The rotation of legumes and forages with grain crops renews nitrogen and improves soil structure (Agriculture Canada 1981a). Soybeans in rotation with corn not only renews nitrogen, but provides a profitable and high feed value alternative to corn (Littlejohns *et al.* 1974). Both, however, are row crops which without proper techniques can lead to soil erosion. In New Brunswick the rotation of small grain cereals with potatoes has proven beneficial in renewing soil organic matter and controlling soil erosion on many larger land holdings.

Better Machinery

Changes in farm machinery have also improved soil husbandry. For instance, high flotation tractor tires make seeding possible on wet, slow-draining fields with a minimum of soil structure damage (Miller 1981). Increased tractor power has reduced field work time requirements. More power can actually lower the risk of soil structure damage because the need to work fields during wet periods is reduced. However, this is only true when operators schedule field work effectively.

Other Controls

In fruit and vegetable production, controls have been developed which in many cases provide alternatives to insecticides. For example, a strain of bacteria (Bacillus thuringiensis) has been used to control the cabbageworm, cabbage looper and the hornworm, while types of microbes known as protozoa have been found to control grasshopper and corn borer populations (Agriculture Canada 1981b). These examples demonstrate that research work can contribute to sustainable as well as high agri-food productivity.

SUMMARY AND CONCLUSIONS

The foregoing examples of unsustainable practices are intended to illustrate the argument for increasing our efforts to conserve land and soil resources for future generations. They do not exhaust the wide range of such practices in use in Canada. Although many cases of resource loss which should be renewable can be cited, it is not clear when the economic significance of these losses will become apparent. Since much of the resource degradation process is irreversible, we should not wait for economic incentives to materialize. The question remains: what can and should this country do to promote conservation of land resources and sustainable agricultural production systems.

Research Findings

One answer is to fully exploit the findings of research in land use, land evaluation and production potential assessment, and land and soil degradation. It is essential that the results of this research be considered in regional development, particularly when the goal is increased production. For example, when bringing new land into production, land which is known to have high risk of soil erosion should not be cleared or left without a ground cover. As well, these findings provide strong arguments for maintaining agricultural use of prime land, rather than urban or industrial use.

Extension

The results of this work must be brought to the attention of the farming population and the public. Progress has been made in the past decade in informing the public of environmental degradation problems. And there appears to be good public awareness of our dwindling agricultural land base (Bentley 1980).

The farm population, however, must acquire more than a general awareness. Farmers must be convinced that conservation practices are worthwhile, even when they mean smaller short-term economic returns. This presents a special challenge in agricultural extension since farmers must be convinced that the risk of land degradation affects their own future financial well-being as well as their children's. Once convinced, they must be advised on the use of such practices. Information on sustainable production practices should also be available through publications. Although much has been written about conservation, many publications are out of date or out of print. There is a need to update this information in the light of current practices, economics and the most recent scientific understanding. When possible, the scientific results should be interpreted in terms of their economic significance. A summary of this information from the farmer's perspective would help realize a sustainable agri-food system.

Financial Incentives

We must also recognize the lack of financial incentives for farmers themselves to ensure future food production capability. Such incentives must be created. Agriculture Canada maintains several financial assistance programs designed to promote technology for higher productivity, e.g., the New Crop Development Fund (Agriculture Canada 1976). But whenever possible, conditions for receiving funds from any existing or new programs should require that the production practices fit the criteria of sustainability. And projects which lead to highly sustainable practices should be emphasized.

Although realizing a sustainable food production system is essential, it will not be achieved easily. Research efforts aimed solely at increased production will usually produce larger immediate payoffs than research directed towards both higher production and sustainability. The same is true in selecting and implementing the available technology. For example, we can no longer afford to promote crop varieties that are just high yielding, without considering their fertility, environmental and management requirements and disease resistance. Making our food production system sustainable will be accomplished at a price, but the long-term cost of the alternative could be much higher.

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Economic indicators

MARKETING AND ECONOMICS BRANCH
QUARTERLY ECONOMIC INDICATORS FOR AGRICULTURE

Item	Units or Base	1979 IV	1979 Annual	1980 I	1980 II	1980 III	1980 IV	1980 Annual	1981 I	1981 II	1981 III
Production and income											
1. GNP at market prices[a]	$ mil.	274 484[b]	261 576[b]	281 688[b]	285 660[b]	294 240[b]	305 888[b]	291 869[b]	318 704[b]	328 704[b]	335 324
2. Farm cash receipts, total[d]	$ mil.	4 096.7	14 258.4	3 847.9[b]	3 484.0[b]	3 969.8[b]	4 507.3[b]	15 809.0[b]	5 547.0[b]	4 070.9	4 463 6
3. — total crops[e]	$ mil.	1 975.6	6 128.7	1 832.4[b]	1 376.6[b]	1 738.1[b]	2 002.1[b]	6 987.4[b]	3 319.3[b]	1 632.3[b]	1 888.4
4. — total livestock[d]	$ mil.	2 031.8	7 733.3	1 913.1[b]	1 996.2[b]	2 132.5[b]	2 350.0[b]	8 385.4[b]	2 121.2[b]	2 269.0[b]	2 331.9
5. Net income rec'd by farm operators[a]	$ mil.	3 700.0[b]	3 617.0[b]	3 200.0[b]	2 812.0[b]	3 412.0[b]	3 768.0[b]	3 298.0[b]	5 240.0[b]	5 288.0[b]	4 704.0
Trade											
6. Agricultural exports	$ mil.	1 884.8	6 107.8	1 501.5	2 008.2	2 003.5	2 331.4	7 844.6	1 906.6	2 112.9[b]	2 167.4
7. Agricultural imports	$ mil.	1 240.4	4 680.6	1 158.9	1 256.9	1 173.6	1 517.8	5 107.2	1 406.5	1 501.7[b]	1 302.5
8. Real domestic product, Ag[a]	1971=100	102.2	103.7	105.8	108.1	105.3	103.7	105.7	115.4[b]	114.0[b]	114.1
9. Real dom. prod., less Ag[a]	1971=100	141.6	151.4	141.0	140.1	140.4	142.6	141.0	144.1[b]	145.9[b]	144.3
Price indexes											
10. Farm input price index	1971=100	239.6	234.9	253.2	250.3	258.6	267.5	257.4	281.2[b]	290.6	298.3
11. — buildings and fencing	1971=100	235.3	226.0	235.5	236.4	242.2	242.7	239.2	247.3	260.6	271.8
12. — machinery & motor veh.	1971=100	205.3	193.3	214.2	221.7	227.0	237.4	225.1	248.0	260.7	270.2
13. — crop production	1971=100	266.5	254.0	296.9	309.1	304.9	310.7	305.4	334.2[b]	343.8	343.9
14. — animal production	1971=100	247.8	249.0	252.7	232.8	256.2	266.8	252.1	269.9	267.4	260.5
15. — hired farm labor	1971=100	237.8	233.6	242.1	245.1	249.2	253.1	247.4	257.7	264.4	268.4
16. — interest	1971=100	395.3	395.3	466.7	460.9	448.7	473.1	462.4	553.7	610.4	673.2
17. Farm prices of Ag. prod.[d]	1971=100	251.9[fb]	255.7[fb]	263.0[fb]	257.7[fb]	284.3[fb]	300.8[fb]	276.4[fb]	299.2[fb]	302.4[fb]	292.9
Input and credit											
18. Farm impl. & equip. sales[a]	$ mil.	N.A.	1 701.0	N.A.	N.A.	N.A.	N.A.	1 745.0	N.A.	N.A.	N.A.
19. Employment in agriculture[a]	'000	481.0	483.8	490.0	478.0	466.0	478.0	478.0	477.0	478.0	547.3
20. Av. farm labor rates	$/h	4.08	3.98	4.15	4.22	4.24	4.31	4.23	4.37	4.44	4.53
21. Av. hourly earnings-manuf.	$/h	7.68	7.44	7.89	8.04	8.28	8.53	8.19	8.78	9.07	9.22
22. F.C.C. — gross loan disburs.	$ mil.	145.2	547.7	98.5	189.6	139.3	95.8	427.4	74.0	171.5	187.0
23. CPI — all items	1971=100	197.6	191.2	202.0	207.6	213.5	219.5	210.6	226.6	233.7	240.6
24. — food at home	1971=100	243.8	238.0	250.3	258.2	270.3	279.4	264.5	288.5	294.8	302.2
25. — food away from home	1971=100	232.4	223.4	237.1	240.7	246.6	251.8	244.1	257.3	264.5	271.2
26. Industry selling price index — food & beverage	1971=100	237.5	231.7	244.2	247.9	260.5[b]	273.8[b]	256.6[b]	275.5	277.4	282.1

continued

MARKETING AND ECONOMICS BRANCH
QUARTERLY ECONOMIC INDICATORS FOR AGRICULTURE (Concluded)

Item	Units or Base	1979		1980					1981		
		IV	Annual	I	II	III	IV	Annual	I	II	III
Other indicators											
27. Unemployment rate	%	7.3	7.5	7.5	7.7	7.5	7.4	7.5	7.3	7.1	7.5
28. Exchange rate	$ U.S.	1.19	1.17	1.16	1.17	1.16	1.18	1.17	1.19	1.20	1.21
29. Chartered banks' rate on prime business loans	%	14.96[b]	12.91[b]	15.25[b]	14.58[b]	12.29[b]	14.92[b]	14.26[b]	18.08	19.25	21.66
30. Quarterly pop. est.	mil.	23.76[b]	23.67	23.83[b]	23.89[b]	23.96[b]	24.03[b]	23.94[b]	24.09	24.15	24.21

[a]Seasonally adjusted at annual rates.
[b]Revised.
[c]Preliminary.
[d]Excludes Newfoundland.
[e]Excluding repair parts.
[f]Based on current initial prices for wheat, oats and barley in Alberta, Saskatchewan and Manitoba.

Sources: All items are from the *Canadian Statistical Review,* Statistics Canada, Catalogue No. 11-003; Agriculture Canada, *Marketing & Economics Branch;* Statistics Canada, Catalogue No. 71-001 and Catalogue No. 21-002; the Farm Credit Corporation; or the *Bank of Canada Review.*

Notes

AGRICULTURAL TRADE SURPLUS HITS NEW RECORD

Canadian agricultural exports chalked up a record $8.8 billion in 1981, up $1 billion from the previous year's figure. Agricultural imports during the same period rose moderately to $5.6 billion from $5.1 billion, resulting in a record $3.2 billion agricultural trade surplus. This is a considerable increase over the 1980 agricultural surplus of $2.7 billion.

Grain, oilseed and meat exports were the main contributors to the large increase in the value of agricultural exports in 1981. Although wheat, Canada's major agricultural export, declined slightly from $3.8 billion to $3.7 billion in foreign sales, barley exports more than doubled to $843 million. Oilseed exports rose to $798 million in 1981, up $150 million from the previous years's level. Of this total, flaxseed exports worth $226 million represented an increase of $90 million from those in 1980, and rapeseed exports increased $40 million to $465 million. Meat exports climbed $106 million to $620 million in 1981. This increase was largely due to fresh and frozen pork exports, which rose $70 million from the previous year's to $349 million. Beef exports increased $20 million to $143 million.

The value of agricultural imports increased about $500 million in 1981. Fruit and nut imports rose $150 million to $1.2 billion. A large part of this increase was in fresh and processed citrus fruits. Vegetable imports reached $601 million, up $131 million from the 1980 level.

EXPANDING MARKET FOR FRESHLY FROZEN FRUITS AND VEGETABLES

Canadian consumers have caught on to the idea of 'freshly frozen' fruits and vegetables. Despite the trend toward fresh products in the 1970s, Canada's frozen fruit and vegetable industry has fared well. In fact, sales of frozen fruits and vegetables have expanded significantly in recent years, according to Dr. Robert Anderson, chief of Agriculture Canada's Horticulture and Special Crops Unit.

Domestic production of frozen fruits was less than 22 500 t in 1974. In 1981, frozen fruit production exceeded 30 000 t. The production of frozen vegetables, other than potatoes, increased even more dramatically in the 1970s. The total volume produced in 1980 was close to 90 000 t, compared with an annual average of about 58 000 t one decade earlier.

Commercial freezing of fruits and vegetables first became a viable industry after the Second World War. Production escalated as improved processing methods resulted in a superior product. Also, expanded freezer capacity at retail outlets and in Canadian homes helped increase the demand for frozen fruits and vegetables.

In recent years, expanding export markets have influenced the growth of the frozen fruit and vegetable sector. Canadian exports of frozen fruits have more than doubled since the early 1970s, reaching 12 600 t in 1980-81. Frozen vegetable exports have expanded from less than 10 000 t in 1974 to nearly 27 000 t in 1980-81. By comparison, frozen fruit imports have declined in recent years, reflecting import replacement by Canadian products. Exports continue to exceed imports, producing a positive trade balance for Canada.

Among frozen fruit products, blueberries have shown the most significant production growth in recent years. Much of this increase results from greater foreign demand and the marketing efforts of major producing provinces such as Nova Scotia, Quebec and New Brunswick. Most blueberry exports go to Western Europe and Japan. Frozen cherries and strawberries are sold mainly in Canada, as quantities are limited. However, British Columbia has developed a substantial market in the United States for its frozen red raspberries.

In frozen vegetables, kernel corn and carrots have had the biggest sales gains. Export demand has stimulated the production of frozen kernel corn, especially for the European market. Sales of green beans and peas have also climbed, largely because consumers like the way these frozen vegetables retain their green color.

Potatoes are a major frozen vegetable product. Exports of frozen french fries, as well as other frozen potato products, have more than doubled since the early 1970s. Over the same period, imports of frozen potato products have remained fairly constant, indicating that Canadian processors are capturing the growth in the domestic market.

According to Dr. Anderson, we haven't yet reached a peak in either production or export demand for frozen fruits and vegetables. There is still an expanding export market for such products as frozen kernel corn and blueberries in France and in the Pacific Rim countries, particularly Japan. Dr. Anderson points out that the high quality of Canadian frozen products is giving Canada's processors a good reputation in export markets. In addition, domestic demand is expected to grow, resulting in more Canadian products replacing imported ones.

ALCOHOL INJECTION FOR DIESEL ENGINES

At Agriculture Canada's Swift Current research station in Saskatchewan, a project is under way to make alcohol a suitable fuel extender in diesel engines. Engines can now be operated by mixing pure alcohol, called anhydrous alcohol, with the gas or diesel oil in a fuel tank. However, this method poses several problems.

Any addition of water, even condensation at low temperatures, can cause the alcohol to separate. Vaporization of the alcohol will result in a loss of power or a stalled engine. To prevent this, pure anhydrous alcohol is used, but it is expensive to produce.

Mark Stumborg and Doug Campbell, two energy engineers at the Swift Current station, are attempting to overcome these difficulties. The engineers have devised an alcohol-injected turbo-charged engine. Included in the design is a separate system to inject the alcohol into the engine. This mechanism is made up of an alcohol tank, alcohol pump, conical spray nozzle and pressure regulator. Since the tanks for the diesel fuel and the alcohol are located separately, less expensive, non-pure alcohol can be used.

The engineers are optimistic about the one-year-old project. No other researchers in Canada are doing work exactly along this line and so far they have had every indication that it will work.

A system of alcohol injection in a turbo-charged diesel engine had been developed in the United States but because the mechanism was poor, work on the project ceased. The basic problem with the American system was that the alcohol was being injected in front of the turbo-charger causing erosion and corrosion of its blades. In the Canadian system, the alcohol is injected after the turbo-charger.

If Mr. Stumborg and Mr. Campbell do succeed in their efforts to build an acceptable alcohol injected turbo-charged diesel engine, the benefits to farmers who use diesel powered tractors will be significant.

NEW PATHOLOBY LAB FOR LETHBRIDGE

Agriculture Minister Eugene Whelan recently announced Treasury Board approval of $1.6 million for the design of a new $23-million pathology laboratory for Agriculture Canada's Animal Disease Research Institute (ADRI) in Lethbridge, Alberta. These new laboratory facilities for the institute will greatly enhance our ability to investigate and control animal diseases in Canada.

It is expected that a construction contract will be awarded in the fall of 1983 with completion of the lab 2 years later. The approximately 2900 m^2 office-laboratory will accomodate 60 staff, including 13 professionals, and replace existing lab facilities built in 1912.

Tests will be performed in the lab to diagnose animal diseases and research carried out to prevent and respond to animal disease outbreaks.

Agriculture Canada has operated ADRI in Lethbridge as a diagnostic and research center since 1905. It is an arm of the Animal Pathology Division of the Health of Animals Directorate in the department's Food Production and Inspection Branch. The work of the lab and the institute supports the branch's responsibility for animal disease control in Canada, meat inspection and certification of disease-free animals and animal products for export.

NEW EXPERIMENTAL FARM IN QUEBEC

The Agriculture Canada quarantine station at St. David, Que., across the St. Lawrence River from Quebec City, has received a new role and a new name. Station quarantine activities for animals have ended in favor of a role as an experimental farm. The new name is the Chapais Experimental Farm, in honor of Jean-Charles Chapais, Canada's first agriculture minister after Confederation, and his son of the same name. Many Chapais descendants still live in Quebec province.

The elder Chapais (1811-85), as a delegate to the Quebec conference of 1864, was a father of Confederation as well as the new country's first agriculture minister. His son (1850-1926) spent most of his adult life as a writer, lecturer, experimenter and public official seeking to upgrade French-Canadian agriculture.

The 24 buildings and about 40 ha of land at the experimental farm had until recently been used as a quarantine station to ensure freedom of disease among animals imported to Canada. An existing station on Grosse Ile, in the St. Lawrence River, and a new station at Mirabel Airport, now serve that function.

Athough we have an extremely active research station at Ste-Foy, which is very near to St. David, there is no land for test plots at the Ste-Foy facility. Scientists have to use land for research purposes as far away as 100 km. The availability of the land and buildings at St. David will make research on test plots much more convenient.

The land and buildings at St. David are being transferred from Agriculture Canada's Food Production and Inspection Branch – which has responsibility for quarantine and disease prevention in Canada – to the department's Research Branch. Research activities are expected to start at the new experimental farm this summer.

Most of the research will center on new cereal and forage varieties developed for production in Quebec by scientists at the Ste-Foy Research Station. The land at the Chapais Experimental Farm, about two-thirds of which is tillable, will be used for test plots. Because buildings on the land have been used for quarantine purposes, no animals will be kept in them for several years. They will be used to store field machinery and other equipment.

SEEDING FORAGES FOR PROFIT

Seeding grass and alfalfa separately can result in superior forage production and increased livestock weight gains. According to Mark Kilcher, a pasture specialist with Agriculture Canada's Swift Current research station in Saskatchewan, when seeded separately in the same field, alfalfa and grass are less competitive, giving the highly nutritious alfalfa time to become better established. This increases yield, improves forage quality and helps extend the productive life of the forage stand.

Farmers can seed alfalfa and grass separately in either alternate rows or in a cross-row pattern. In the first method the rows are spaced 45 – 60 cm apart. In the second method the grass is planted in one direction in rows 90 cm apart and then the alfalfa is planted at right angles to the grass in rows 90 cm apart.

The cross-row pattern has the added advantage of helping trap more water and reduce soil erosion. It also provided the greatest liveweight gains in feeding trials conducted at the research station using cows and calves or yearlings. The alternate-row stands produced 13% more liveweight gain than did mixed stands while the cross-row stands yielded 30%more liveweight gain.

According to Mr. Kilcher, a producer can expect seeded pastures to yield five to seven times the liveweight gain possible on native rangeland.

WINTER CEREAL IN NOVA SCOTIA

Cereal production in Atlantic Canada is getting a boost from a new government-agribusiness project. A winter cereal management project was started last fall by the Minas Seed Coop Ltd. of Canning, N.S., with help from Agriculture Canada's New Crop Development Fund.

The aim of the 6-year project is to increase cereal production in the province from its current base of 3000 ha to 12 000 ha.

Gary Koestler, secretary of the fund in Ottawa, says that winter wheat production in Nova Scotia has been increasing at an impressive rate in recent years. Farmers in that province, New Brunswick and Prince Edward Island are becoming more interested in growing milling wheat for human consumption.

The federal government is contributing $25 000, or half the total cost of the project for the first year. Additional funding will be determined later this year to help cover the project costs in future years. Also, technical support is being provided by experts at Agriculture Canada's research station in Kentville, N.S., and Dover Mills Ltd. in Canning.

The project will identify the best cereal varieties and management systems suited to Atlantic Canada's climate. Three winter wheat varieties and a winter rye variety will be tested first. Other promising varieties will be incorporated into the project after a 3-year review at the end of 1984.

Five cereal management systems currently used in Europe will be studied: the Holstein, Heyland, Lalaux, Extensive and Continous cropping systems. The principal differences between these systems include the seeding rates and dates, the amount and timing of fertilizer and growth regulator application, disease control methods and varying demands on a farmer's time.

The European systems are being looked at because the major cereal producing regions there have similar climatic conditions to the Atlantic Provinces. Atlantic farmers face excess moisture and high humidity that increase the danger of lodging and fungal diseases.

The costs of the various management systems will be compared, as will crop development. The quality and market value of the crop will be assessed on milling, protein, baking and grading test results. The cereals will also be assessed for their potential as livestock feed.

FARMBANK

FARMBANK is a computerized commodity data base maintained by Agriculture Canada's Marketing and Economics Branch. It contains approximately 1000 regional, national, and international food and agriculture data series for prices, production, stocks, consumption, imports, exports for all major grains and livestock products, as well as farm income statistics, retail prices and general economic data.

FARMBANK data are mainly quarterly, and originate as far back as 1950. They are collected from Agriculture Canada and other Canadian, U.S. and international sources.

FARMBANK is now available on-line for a monthly fee from the Conference Board of Canada and Datacrown Inc. Prospective clients may contact their marketing representatives for more information about the data base and how to access this information.

The marketing representative for the Conference Board of Canada is Mrs. Viviane Paré; the address is 25 McArthur Ave., Vanier, Ontario, K1L 6R3. Datacrown Inc.'s representative is Mr. Jim Dunn; the mailing address is 770 Brookfield Road, Ottawa, Ontario, K1V 6J5.

NOTE

Please note that the appendix of 1980 price assumptions for the Russell and Colwell article which appeared in our December 1981 issue is available from the editors.

Publications

Note to readers: For their discussion papers the Institute of Economic Research, Queen's University, Kingston, Ontario, charges $2.00 per paper to cover publication costs, postage and handling. (See CFE Vol. 16, No. 1.)

The following eight publications are available without charge from the Distribution Center, Room B 151, R.D. and I.A. Branch, Agriculture Canada, Ottawa K1A 0C5.

An Economic Analysis of the Crow Rates. Economic working paper by David R. Harvey, Department of Agricultural Economics, University of Newcastle upon Tyne, England, 37 pp.

Fertilizer Statistical Bulletin. Edward Suen, Publication No. 82/2, March 1982, 50 pp.

Food Market Commentary. Vol. 4, No. 1, March 1982, 50 pp.

Handbook of Food Expenditures, Prices and Consumption. Zuhair A. Hassan and Danielle Karamchandani, Publication No. 81/5, December 1981, 290 pp.

List of Material Published in 1981 by Members of the Marketing and Economics Branch and Regional Development and International Affairs Branch. A. Trempe, Publication No. 82/1, March 1982, 7 pp.

Market Commentary – Animals and Animal Products. March 1982, 49 pp.

Market Commentary – Grains and Oilseeds. March 1982, 48 pp.

Market Commentary – Milk and Dairy Products. March 1982, 21 pp.

The following six publications are available free from the Economics Branch, Ontario Ministry of Agriculture and Food, Legislative Buildings, Toronto, Ontario M7A IB6.

The Economics of Soybean Production in Ontario, 1980. G.A. Fisher, Economics Information Series, December 1981, 40 pp.

On-Farm Drying and Storage Costs for Corn, Ontario 1978 and 1979. G.A. Fisher, Economics Information Series, December 1981, 20 pp.

Rural Real Estate Prices in Ontario, 1979. Tonu Tosine and Walter Kresovic, Economics Information Series, March 1981, 55 pp.

A Selected List of Branch Publications 1982. Mary Hurst, Economics Information Series, 8 pp.

A Survey of Custom Farmwork Rates Charged in Ontario, 1981. G.A. Fisher, Economics Information series, January 1982, 24 pp.

The Turkey Industry in Ontario. A. Contini, Economics Information Series, July 1981, 163 pp.

Canada's Agricultural Systems – Fourth Edition. Collated by Roy Kennedy and Malcolm Churches. This edition is an updated and considerably expanded version of earlier editions of this reference manual which was produced and is used for courses in the Faculty of Agriculture, McGill University. The authorship has changed each time but the book continues to draw from other sources, including various publications from Agriculture Canada. The book provides an integrated description of the Canadian Agriculture and Food System, plus the system's crop and livestock commodity subsystems. *The manual is available for $20.00 from the Department of Agricultural Economics, Macdonald Campus of McGill University, 21111 Lakeshore Road, Ste. Anne de Bellevue, Quebec H9X 1C0.*

Agricultural Computing Newsletter. *Available for U.S. $60 a year from Agricultural Computing, Doane-Western Inc., 8900 Manchester Road, St. Louis, Missouri 63144.*

Agricultural Microcomputing Newsletter – Information for Ontario Farmers. Editor: R.W. Ross. *Available from the Farm Economics Section of the Ridgetown College of Agricultural Technology, Ridgetown, Ontario N0P 2C0.*

The Capitalization of Flood Hazard into Land Prices in Manitoba's Red River Valley. N. Senjem and D. Freshwater, Research Bulletin No. 81-82. December 1981, 53 pp. *Available free from the Department of Agricultural Economics, 403 Agriculture Building, The University of Manitoba, Winnipeg, Manitoba R3T 2N2.*

COMPU-FARM. *Available free from Alberta Agriculture, Box 2000, Olds, Alberta T0M 1P0.*

Farm Computer News – Successful Farming Magazine. *Available for U.S. $40 a year from 1716 Locust Street, Des Moines, Iowa 50336.*

Feeding and Management Guide for Growing Beef Cattle. R.R. Corbett P.Ag., September 1981, 36 pp. *Available free from the Publications Office, Ministry of Agriculture and Food, Parliament Buildings, Victoria, British Columbia V8W 2Z7.*

In reply

We appreciate your letters and comments on articles in *Canadian Farm Economics.* When forwarding your 'In Reply', or letter, please indicate if we may publish your comments in a subsequent issue.

Professor R. Butler of the University of Saskatchewan's Veterinary College, Saskatoon, wrote to say that he found particularly useful two articles in our August 1981 issue: "An Economic Analysis of Alternative Management Techniques for Beef Production on Irrigated Pastures in Alberta," by K.D. Russell *et al.*, and "Economics of Crop and Livestock Production in Saskatchewan," by M.M. Sorboe. He also thought that the Publications section was very useful.

B.R. Lewis, President, Lewis Farms Ltd., Birch Hills, Saskatchewan, liked "Recent Developments in Economic Data at Agriculture Canada," by W. Darcovich in the same issue but had reservations about the Sorboe article. "While this article includes a good approach of determining answers needed, the key thing is that the answers were needed 3 years ago. Much more harm than good is done by publishing obsolete data." The author did note in his article, however, that an update of the data would be necessary to simulate the current situation. It is the changes in farm structure shown in this article which are important, not the figures themselves. Mr. Lewis also found Economic Indicators and Notes very useful.

Michael Dilauro, an analyst with the National Energy Board, Ottawa, wrote that the farm cash expenses in the August issue were "very useful in trying to estimate demand for petroleum products."

Ray Rivers, an economist-farmer from Russell, Ontario, wrote about the October 1981 issue. He said that the Economic Indicators, Notes and Publications were very useful but that he didn't like "A Scheme for Defining Drought Areas," by Dyer *et al.* He said that he would like to see more practical articles like the one by S. Al Hassan *et al.* in the same issue.

We heard from several readers regarding our December 1981 issue. Professor J.A. Boan, Professor of Economics at the University of Regina, was interested in economic indicators over a longer historical period. We provided him with figures going back to the first quarter of 1973. Professor Boan found the trade article by Labrosse and McSorley and the criteria for drought article by Dyer *et al.* most useful. Others who particularly liked the article on Canada's agricultural trade were Dr. Hak-Yoon Ju of the Nova Scotia Agricultural College, Truro and Bruce Wither, a grain trader with Victory Soya Mills Ltd., Toronto.

IN REPLY TO AUTHORS AND EDITORS REGARDING VOL. 17, NO. 3, SUMMER 1982
CANADIAN FARM ECONOMICS

I have read	*and on a scale of 0 to 10, found it* *not useful*		*very useful*
D. Ricard	0	5	10
A.C. Grant	0	5	10
J.A. Dyer	0	5	10
Economic indicators	0	5	10
Notes	0	5	10
Publications	0	5	10

Comments on (name of section of article) ____________________

Do you have any other suggestions or questions on the contents of this issue?

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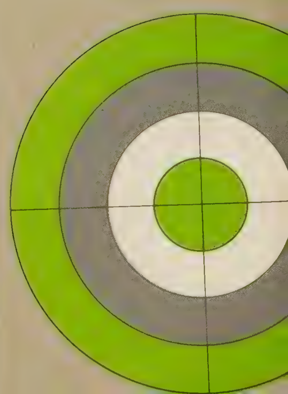

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EDITORIAL SERVICE

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Carmen Hodgson, *French Editor*

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Letters from readers: Letters are encouraged and should be addressed to the managing editor. Comments and suggestions are useful to editors and authors for effective two-way communication. Edited letters will be used in CFE with the writer's permission.

HON. EUGENE WHELAN, MINISTER
J.P. CONNELL, DEPUTY MINISTER

Market structure and economic performance of the food processing and farm input industries in Canada

This paper uses an empirical model for evaluating the nature of industrial performance influenced by market structure variables in 25 farm input and food processing industries in Canada during the 1970s. Performance is represented by two variables – the price-cost margin and the percentage change in price. The estimated equation for the price-cost margin exhibits a lack of statistical significance of the concentration variable, while foreign ownership and income elasticity are positively related to the price-cost margin and are statistically significant. The results of our analysis suggest that the structure-performance paradigm may have given too much weight to concentration as an explanatory variable for industrial performance. The degree of foreign ownership is an important explanatory variable in Canada but it has been neglected in the earlier quantitative studies.

S.M.H. Rizvi and Ihn H. Uhm

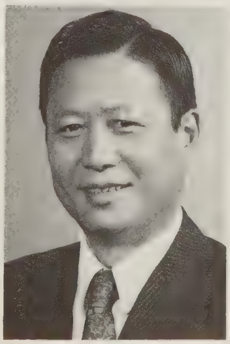
INTRODUCTION[1]

During the past 3 decades, the growth of food processing and farm input firms has disturbed the balance of market power between these firms and farmers. As a result, the farming sector has to interact with a highly concentrated business sector. Research economists in Canada and abroad have recognized this shift in the distribution of market power as crucial, and have repeatedly shown their interest in evaluating the relationship between this newly evolved business structure and the overall performance of the industries containing these firms.

[1] This paper was originally presented at the annual meeting of the Canadian Agricultural Economics Society, Brock University, St. Catherines, Ontario, August 9-12, 1981.

Dr. Saiyed H. Rizvi, an economist with Strategy Planning and Evaluation Branch, was until recently with the Marketing and Economics Branch.

Mr. Ihn H. Uhm is an economist with the Research Branch of the Canadian Transport Commission.



A review of the literature pertaining to this issue reveals that many attempts have been made in the United States and Canada to investigate empirical relationships between the structural variables and industrial performance in the manufacturing industries. Only a few of these studies, however, have actually tried to isolate the nature and significance of these relationships, especially in the food processing and farm input industries of the U.S. and Canada.

The Hypothesis

This paper uses an empirical model for evaluating the nature of industrial performance influenced by market structure variables. It is based on 25 farm input and food processing industries in Canada during the 1970s. We tested the following two hypotheses by using multivariate regression analysis technique:

1. All things being equal, the profit rate (as represented by the price-cost margin) will be greater in industries with higher seller concentration, product differentiation, income elasticity, industry growth rates and tariff protection. Since foreign ownership is an important market structure variable in Canada, we attempted to include it in our price-cost margin equation as one of the explanatory variables. The expected sign of this variable is, however, not clear *a priori*; it depends on the degree to which transfer pricing is prevalent among the foreign-owned firms in the food processing and farm input industries.

2. Similarly, all things being equal, the rate of price change will be higher in industries with higher seller concentration, product differentiation, percentage change in direct cost and industry growth rate.

REVIEW OF THE LITERATURE

Since 1951, the year when J.S. Bain published his paper "Relations of Profit Rate to Industry Concentration," some economists have undertaken cross-sectional and time-series studies to examine the influence of prominent structure variables on industry performance in the manufacturing sector. Some of the most relevant of these studies included those by Collins and Preston (1966), McFetridge (1973), Comanor and Wilson (1967), Bloch (1974), Porter (1979), Philips (1976), Khalilzadeh-Shirazi (1974), De Silva (1971), Dale Orr (1974), Kwoka (1978), Jones, Landadio and Percy (1977), Louis Esposito and Frances Esposito (1971),

Schemalensee (1976) and Hazeldene (1978). Salient conclusions of some of these studies' methodology relevant to our study follow.

Comanor and Wilson found that advertising has a statistically significant and quantitatively important impact upon profit rates. This provides a measure of market performance and indicates the existence of market power. In industries whose products are differentiable, advertising investment is highly profitable. In addition, Comanor and Wilson noted a significant joint impact on profit concentration rates and the entry barriers created by scale economies and high capital requirements. However, the authors detected the impact of product differentiation to be as important as that of other structure variables such as concentration. The Collins and Preston study strongly supports the hypothesis that certain key features of industry structure are closely associated with variations in the price-cost dimension of market performance. They analyzed cross-section data of 32 food manufacturing industries for 1958. Their main conclusion was that average industry price-cost margins are positively related to the degree of concentration. They found the relationship between these two variables to be continuous and curvilinear.

McFetridge reported the results of an econometric investigation of the links between industry price-cost margins and elements of industry structure in a cross-section of 43 Canadian manufacturing industries during 1965-69. His main finding was that with the growth rate of demand and the level of capital investment, inter-industry differences in price-cost margins are significantly correlated with a variety of seller concentration measures. This correlation is relatively more prominent in consumer good industries than in producer good industries.

De Silva showed that industrial concentration was not an important factor in the price increases in the manufacturing sector during the 1960s. He concluded that increases in unit costs had an impact on price increases in many industries, regardless of the degree of concentration.

Bloch, referring briefly to the findings of previous empirical studies which establish a positive relationship between profit rates and advertising intensity, uses a different measure for profit rates which he calculates by treating advertising expenditures as an investment in capital assets. The author finds no significant relationship between corrected profit rates and advertising intensity. Bloch argues that the positive association between profit rates and advertising, as found in most of the previously conducted investigations, was due to unappropriated accounting of advertising expenses.

The paper by Jones, Landadio and Percy (1977) is a unique attempt to test the comparative structure-performance relationship using multiple regression techniques for a cross-section sample of 60 Canadian and 69 U.S. manufacturing industries. The 60 Canadian manufacturing industries were divided into 31 consumer-good and 29 producer-good industries for the period 1965-1967. The authors successfully demonstrated that as different independent variables have different impacts on profits in consumer- and producer-good industries, any attempt to generalize about structure-performance relationships must clearly distinguish between consumer and producer goods.

Another paper by the same authors (1973) reported the results of regressing the profitability of a sample of 30 Canadian consumer-good industries on various measures of market structure in 1965. They found that first, the impact of structural variables on one dimension of performance is more complex than is often assumed, and second, foreign competition is an important determinant of variations in domestic profits although the relationship is again complex.

Schumalensee, in his more theoretical exposition, deals with the studies on the overall impact of advertising outlays on profitability through its effects on entry barriers and ease of collusion. In his attempt to test the null hypothesis that no such effects exist, the author reveals some of the difficulties encountered when using certain cross-sectional studies as tests.

Most of the foregoing studies have concentrated on structure variables originating within the domestic domain. Esposito and Esposito tackled the question of inter-industry variations in profitability caused by actual and potential foreign competition. They examined the influence of foreign competition as determined by import levels. Their conclusions suggest that in industries where foreign firms are the least disadvantaged potential entrants, established firms will likely set prices lower than those necessary to discourage potential domestic entry. The negative and significant relationship between imports and profits is consistent with the hypothesis that in certain markets the threat of potential foreign entry exerts the most important influence on the 'immediate' condition of entry. As a policy implication they arrive at a conclusion that decreases in tariffs would tend to result in more competitive pricing in industries where foreign entry substantially threatens domestic industry's profitability.

THE MODEL

We used the following multiple regression model (implicit form) to test our basic hypotheses. Also included are the definitions of both dependent and independent variables and data sources.

1. M $= f_1$ (CR_4, CR_4ASS, FOR, INE, IMP, EXP, DY, VS, ETAR, e)
2. P $= f_2$ (CR_4, CR_4ASS, CR_4FOR, W, F, M, VS, e)

where the two dependent (performance) variables were:

M $= \text{price-cost margin} = \dfrac{\text{value added-wages}}{\text{value added}}$

(Statistics Canada 1971-77 inclusive)

P = percentage change in Industry Selling Price Index (ISPI) calculated by using ISPI data as

$$\frac{P_{1977} - P_{1971} \times 100}{P_{1971}}$$

(Statistics Canada 1971 and 1977)

and the 16 independent variables:

CR_4 = 4-firm concentration ratio (Statistics Canada 1972, 1974 and 1976)

CR_4ASS = 4-firm concentration ratio multiplied by the advertising ratio

CR_4FOR = 4-firm concentration ratio multiplied by the share of foreign ownership

W = percentage change in wages (Statistics Canada from 1971 to 1977)

F = percentage change in the cost of fuel and electricity (Statistics Canada from 1971 to 1977)

MS = percentage change in the cost of material and supplies (Statistics Canada from 1971 to 1977)

VS = percentage change in the value of shipments representing growth of demand (Statistics Canada from 1971 to 1977)

C = percentage change in total costs, comprising wages, cost of fuel and electricity and cost of material and supplies (Statistics Canada from 1971 to 1977)

ASS = ratio of advertising expenses to value of shipments (Statistics Canada 1965)

FOR = percentage of industry shipments accounted for by foreign-owned firms (Statistics Canada 1972, 1974 and 1976)

INE = income elasticity of demand (Agriculture Canada for the 1970s)

IMP = ratio of imports to total domestic sales (Statistics Canada 1977)

EXP = ratio of exports to value of shipments (Statistics Canada 1977)

DY = dummy variables representing industries with government intervention

CR_8 = 8-firm concentration ratio (Statistics Canada 1972, 1974 and 1976)

ETAR = effective tariff rate adopted from Wilkinson and Norrie

e = error term

EMPIRICAL RESULTS

While various types of mathematical form were tested by using the ordinary least squares (OLS) method for goodness of fit and predictive capability at the preliminary stage, that of linear and log-linear forms had performed reasonably and consistently well among alternative specifications. Estimates of the two models obtained with the OLS method are in Tables 1 and 2.

Structure and Price-cost Margin

Based on the eight selected equations in Table 1, it is clear that log-linear equations (i.e., equations 4 and 8) performed better than linear equations in terms of the F-test, and are significant at more than the 5% level. Contrary to our *a priori* expectation, the concentration variable (either CR_4 or CR_8) is not statistically significant. In addition, its sign turned out to be opposite for the results of food processing industries alone (20 industries) and combined food processing and farm input industries (25 industries).

This implies that the concentration ratio does not exert a statistically significant influence on the price-cost margin for the chosen industry sample during the 1971-77 period. We can offer two explanations at this point: (1) concentration does not play a major role in determining the price-cost margins in the food processing industries (i.e., consumer-good industries), and (2) during the double-digit inflationary period (the 1970s), concentration did not occupy the central place that is often assumed.

Instead of concentration, other market structure variables, such as foreign ownership (FOR) and income elasticity (INE), were found to be important determinants of performance as they are statistically highly significant. Since these variables are positively related with the price-cost margin, the higher the degree of foreign ownership in an industry, the higher the price-cost margin. Similarly, the industries producing goods with high income elasticity tend to have a high price-cost margin.

A dummy variable used to represent those industries regulated by government was assigned a value of 1 while the others were assigned 0. This variable was statistically moderately significant, and its sign turned out to be negative, indicating that industries with government intervention tend to have, on the average, lower margins. All remaining structure variables specified in the equation were statistically insignificant.

Structure and Percentage Change in the Price Relationship

The equations in Table 2 represent the administered-inflation hypothesis, in which price increases are larger in concentrated than in unconcentrated industries (Weston and Lustgarten). All equations shown in Table 2 are statistically significant at more than the 5% level. Contrary to the hypothesis, the concentration variable is negatively related to the percentage change in price. The CR_4 variable is statistically highly significant, i.e., the higher the degree of concentration, all things being equal, the lower percentage changes in price. This suggests more stable prices during inflationary periods for industries with high concentration. However, industries with high concentration combined with a high degree of product differentiation tend to have

TABLE 1. MULTIPLE REGRESSION RESULTS FOR PRICE-COST MARGINS[1]

Equation number	Constant	CR_4	CR_4 ASS	FOR	INE	IMP	EXP	DY	ΔVS	CR_8	ETAR	F	R^2	$\bar{R}^2$	N
	Farm inputs and food processing industries														
1	0.617	$-0.125^{(-2)}$ (-0.857)	$0.161^{(-3)}$ $(1.152)^2$	$0.201^{(-2)}$ $(1.644)^3$	0.140 $(1.852)^4$	$0.942^{(-3)}$ (0.654)	$-0.662^{(-4)}$ (-0.055)	$-0.854^{(-1)}$ $(-1.644)^3$	–	–	–	3.098	0.625	0.423	25
2	0.608	$-0.121^{(-2)}$ (-0.780)	$0.169^{(-3)}$ (1.023)	$0.192^{(-2)}$ $(1.295)^2$	0.137 $(1.590)^3$	$0.948^{(-3)}$ (0.632)	$-0.108^{(-3)}$ (-0.084)	$-0.857^{(-1)}$ $(-1.584)^3$	$0.482^{(-2)}$ (0.110)	–	–	2.506	0.626	0.376	25
3	0.608	$-0.726^{(-3)}$ (-0.190)	–	$0.173^{(-2)}$ $(1.688)^3$	0.206 $(4.047)^5$	–	–	–	–	$-0.156^{(-4)}$ (0.000)	$-0.345^{(-3)}$ (-0.197)	4.486	0.541	0.420	25
4	-0.300	$-0.896^{(-1)}$ (-0.955)	–	0.131 $(2.154)^5$	0.127 $(3.930)^5$	–	–	–	–	–	–	6.813	0.493	0.421	25
	Food processing industries only														
5	0.616	$-0.123^{(-2)}$ (-0.691)	$0.158^{(-3)}$ (0.853)	$0.202^{(-2)}$ $(1.256)^2$	0.140 $(1.243)^2$	$0.909^{(-3)}$ (0.477)	$-0.740^{(-4)}$ (-0.055)	$-0.851^{(-1)}$ $(-1.448)^3$	–	–	–	1.808	0.535	0.239	20
6	0.585	$-0.125^{(-2)}$ (-0.669)	$0.164^{(-3)}$ (0.834)	$0.199^{(-2)}$ $(1.179)^2$	0.149 $(1.170)^2$	$0.853^{(-3)}$ (0.423)	$-0.132^{(-3)}$ (-0.089)	$-0.822^{(-1)}$ $(-1.288)^2$	$0.149^{(-1)}$ (0.179)	–	–	1.447	0.536	0.166	20
7	0.589	$-0.283^{(-2)}$ (-0.649)	–	$0.210^{(-2)}$ $(1.554)^3$	0.219 $(2.206)^5$	–	–	–	–	$0.181^{(-2)}$ (0.409)	$-0.918^{(-3)}$ (-0.473)	1.757	0.386	0.166	20
8	-0.404	$-0.825^{(-1)}$ (-0.692)	–	0.146 $(1.994)^4$	0.116 $(2.283)^5$	–	–	–	–	–	–	3.234	0.377	0.261	20

[1] Figures in parentheses are t values. The significance of the regression coefficients is tested using the t-test and the significance of multiple determination is tested using the F-test. Bracketed exponent figures are decimal point adjustments, e.g. $0.161^{(-03)} = 0.000161$.

[2] Indicates significance at more than 30% – two-tail test.

[3] Indicates significance at more than 20% – two-tail test.

[4] Indicates significance at more than 10% – two-tail test.

[5] Indicates significance at more than 5% – two-tail test.

[6] Log-linear equation.

TABLE 2. MULTIPLE REGRESSION RESULTS FOR PERCENTAGE CHANGE IN PRICES[1]

Equation number	Constant	CR_4	CR_4 ASS	CR_4 FOR	ΔW	ΔF	ΔMS	ΔVS	ΔC	F	R^2	$\bar{R}^2$	N
	Farm inputs and food processing industries												
1	44.810	−0.783 (−2.344)[2]	0.047 (1.344)[3]	—	0.294 (3.022)[2]	0.219 (1.940)[4]	—	1.109 (1.041)	—	5.151	0.632	0.509	25
2	38.124	−0.805 (−2.423)[2]	0.044 (1.280)	—	0.343 (3.224)[2]	0.273 (2.233)[2]	−0.112 (−1.100)	0.163 (1.413)[3]	—	4.555	0.661	0.516	25
3	46.324	−0.562 (−2.244)[2]	—	—	0.343 (3.140)[2]	0.269 (2.412)[2]	−0.053 (−0.539)	—	—	5.097	0.560	0.450	25
4	117.510	1.323 (−3.097)[2]	—	$0.100^{(-1)}$ (2.666)[2]	—	—	—	—	0.146 (2.304)[2]	6.210	0.523	0.439	25
	Food processing industries only												
5	40.946	−0.679 (−2.111)[2]	0.051 (1.570)[3]	—	0.247 (2.493)[2]	0.120 (0.993)	—	0.286 (1.467)[3]	—	4.931	0.655	0.522	20
6	33.556	−0.741 (−2.727)[2]	0.047 (1.730)[3]	—	0.356 (3.794)[2]	0.223 (2.039)[4]	−0.227 (2.525)[2]	0.346 (2.090)[4]	—	6.871	0.775	0.662	20
7	53.508	−0.611 (−2.774)[2]	—	—	0.414 (4.182)[2]	0.289 (2.959)[2]	−0.208 (−1.977)[4]	—	—	6.000	0.632	0.526	20
8	119.104	−1.314 (−2.742)[2]	—	$0.978^{(-2)}$ (2.272)[2]	—	—	—	—	0.125 (1.513)[3]	3.420	0.407	0.288	20

[1] Figures in parentheses are t values. The significance of the regression coefficients is tested using the t-test and the significance of multiple determination is tested using the F-test. Bracketed exponent figures are decimal point adjustments, e.g., $0.978^{(-2)} = 0.00978$.

[2] Indicates significance at more than 5% — two-tail test.

[3] Indicates significance at more than 10% — two-tail test.

[4] Indicates significance at more than 20% — two-tail test.

TABLE 3. SOME SELECTED STUDIES OF MARKET STRUCTURE RELATIONSHIP TO PROFITABILITY

Author	Dependent variable measure	Variable representing structure	Coverage	Period	Main findings
Jones, Laudadio and Percy (1977)	Profits = ratio of profits plus interest to total assets	4-firm concentration (CR_4)	31 consumer-good and 29 producer-good industries in Canada	1965-67 inclusive	A positive and significant relationship between concentration and profit for producer goods, insignificant for consumer-good industries
McFetridge (1973)	$\text{Margin} = \frac{\text{value added-wages}}{\text{value added}}$	Herfindahl index (H)	43 manufacturing industries in Canada (3 digit)	1965-69 inclusive	A positive and significant relationship between concentration (measured by H^2) and price-cost margin
Collins and Preston (1966)	$\text{Margin} = \frac{\text{av. price-av. cost}}{\text{av. price}}$	4-firm concentration (CR_4)	32 food processing industries in the U.S.	1958	A positive and significant relationship between concentration and price-cost margin (curvilinear relationship)
Hazledine[1] (1978)	$\text{Margin} = \frac{\text{value added-wages}}{\text{value of shipments}}$ $\text{Surplus} = \frac{\text{value added-wages}}{\text{normal returns}}$	4-firm concentration (CR_4) and $(CR_4)^2$	19 food processing industries in Canada	1961-74 inclusive	Non-linear relationship between concentration and margin or surplus
De Silva (1971)	Percentage change in industry selling-price index	Concentration ratio (CR_4)	26 manufacturing industries in Canada	1961-67 inclusive	Concentration variable not found to be statistically significant
Present study by Rizvi and Uhm	$\text{Margin} = \frac{\text{value added-wages}}{\text{value added}}$ $P = \frac{P_{t+n} - P_t}{P_t} \times 100$	4-firm concentration (CR_4) 8-firm concentration (CR_8) Concentration jointly with product differentiation	20 food processing industries and 5 farm input industries in Canada	1971-77 inclusive	A negative and significant relationship between concentration and percentage change in price, but negative and insignificant relationship between concentration and margin

[1] Working paper

greater price increases, since the CR_4ASS variable is positively related to price changes and is statistically significant.

Variables representing the percentage change in the cost of production or change in demand are also important determinants of the price equation. Percentage changes in wages (W), fuel and electricity (F), and demand (VS) are all positively related with percentage changes in price and are statistically significant. However, the industries with a higher percentage change in material costs are associated with the lower rate of price change, as indicated by the negative sign of the material cost variable (MS). In essence, the findings indicated that industries faced with higher percentage increases in wages and fuel and electricity costs have experienced higher percentage increases in price, while industries with higher percentage increases in material costs have had lower percentage changes in price. In addition, as indicated by CR_4ASS, the concentrated industries with a high degree of product differentiation showed higher percentage increases in price.

As indicated by C in Table 2, overall cost increases is an important factor affecting the percentage change in price. The combined effects of the degree of foreign ownership and concentration also explains variation in the dependent variable.

Comparisons with Previous Studies

Table 3 presents the major findings of this study and selected previous studies. Although the concentration variable has played for a long time a central role in explaining the performance of manufacturing industries in the literature of industrial organization, there are conflicting empirical results to support the central doctrine of the structure-performance paradigm, i.e., that concentration necessarily leads to higher profit or price-cost margins.

As shown in Table 3, concentration, as an explanatory variable for the price-cost margins, was statistically significant during the 1950s and 1960s for manufacturing industries (though results are not conclusive when samples are divided between consumer-good and producer-good industries). In addition, results are also sensitive to the selected periods. The relationship does not hold for food processing industries (or combined with farm input industries) in Canada in the 1970s, which saw double-digit inflation. The role of concentration in relation to the percentage change in the price level is either unimportant or contrary to *a priori* expectations, i.e., it is a negative relationship.

SUMMARY AND CONCLUSIONS

This study by no means claims that the model presented here is definitive or exhaustive. It is rather an attempt to represent the structure-performance paradigm. Performance, involving the social performance of the industry, is represented by two variables – the price-cost margin and the percentage change in price. The estimated equation for the price-cost margin exhibits a lack of statistical significance of the concentration variable, while foreign ownership and income elasticity are positively related to the price-cost margin and statistically significant. The concentration variable is negatively related to the percentage change in price and statistically highly significant. The concentration variable has played a central role in market structure, conduct and performance literature, but the results of our study suggest that while concentration does have some significance, it does not appear to occupy the central place in the Canadian food processing and farm input industries. The structure-performance paradigm may have given too much weight to concentration as an explanatory variable for industry performance. The degree of foreign ownership is an important explanatory variable in Canada but it has been neglected in the earlier quantitative studies.

A further study should be conducted to obtain a better understanding of the effects of the oligopolistic nature of the Canadian food processing and farm input industries on the welfare of farmers as they purchase inputs from and sell products to such industries. Although this study did not address this question, it attempted to pave the way for future research.

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A weather-based early warning system for spring forage in western Canada

This paper describes a system for providing early warning for drought prospects in the Prairie Provinces. Soil moisture reserves under perennial forage are estimated for May 31 by replacing historical weather data with the most recent daily weather observations as they become available. Projections from the end of January, February, March and April are compared with estimates made at the end of May in each test year. Projections from January through March provide reasonable outlooks for the general drought prospects at the end of May.

J.A. Dyer, R.B. Stewart and R.W. Muma

INTRODUCTION[1]

This paper describes a weather-based, early warning system for potential areas of drought in the Prairie Provinces. The information is directed at decision makers for government intervention and at drought-proofing efforts. Drought proofing can include advice on farm management decisions and financial assistance to drought victims. Before the impact of drought can be dealt with effectively, it must be recognized that the effects of drought can differ widely and that each must be considered individually. Our system is concerned with the availability of a spring pasture crop for the western beef production industry, and particularly with the moisture reserve levels for perennial forage growth.

[1] This paper was originally presented in a different form at the Agricultural Institute of Canada meeting in Vancouver, B.C., July 11-15, 1982.

The target area of the Prairie Provinces includes 30 sites which provide current weather data. The system described here provides a pre-season reconnaissance of potential problem areas, but is not an accurate description of the areas that will actually suffer from drought later in the season. Such a delineation would require more weather data than are being analyzed. This Forage Drought Early Warning System (FoDEWS) operated during the 1982 season as a pilot project, with biweekly and monthly reports issued from January to June.

BACKGROUND

The need for an effective early warning system was recognized after assessing drought assistance needs during the 1980 and 1981 spring seasons. A need was also identified to define criteria for drought and to accurately map drought zones. These two concerns have been dealt with in two previous studies (Dyer *et al.* Oct. 1981; Dec. 1981). Although this paper deals only with monitoring drought, meaningful and reliable criteria for drought severity are essential to an effective drought monitoring scheme.

To implement drought proofing measures which are both fair and timely, lead time is required. Therefore, reports of drought risk are predicted one or more months in advance, too long a period for accurate forecasts using physically based methods. Since the reported risks are based on historical patterns, we prefer to describe them as projections. The accuracy with which an event can be predicted depends on the role of previous events and the degree to which the

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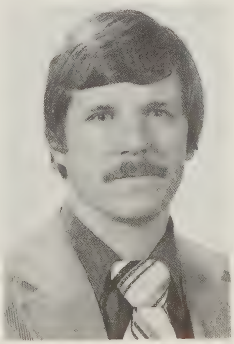


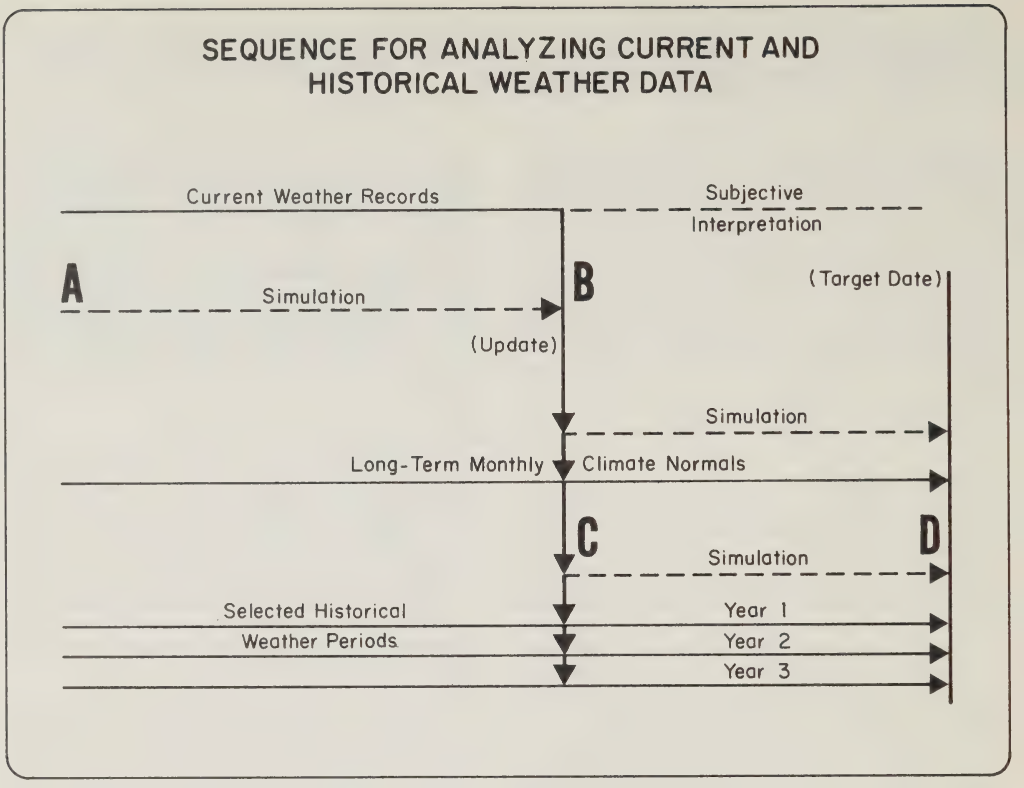


Figure 1

relationships between the previous events and the predicted events are understood. The previous events that we use here are plant water use during the previous growing season, fall and winter precipitation and spring melt. Other factors in the relationships are water storage, both by snow and soil, and plant water use characteristics.

The projections are made by computer simulation. An advantage of this approach is that it can be applied identically to both past and present conditions since it is based on weather records. As well, all projections are expressed as estimated conditions for May 31, even though they may be made in January or February. The target date concept simplifies computer operation procedures by standardizing model controls and output. It also enhances the use of statistical criteria for drought severity levels. Making projections also assumes that by late winter much of the risk of drought has already been decided, without yet knowing how much spring rain there will be.

Another type of drought monitoring is the simple recording of precipitation records as they become available. An example is the biweekly weather report for agriculture in Alberta, which includes maps of average temperature and total precipitation. An advantage of simple weather reporting is that a variety of subjective interpretations can be made. Also, data from a larger number of collection sites can be used, since missing records can be replaced by estimates without affecting the reports. Such maps have their place; however, to make objective statements of conditions from weather data, more detailed analytical procedures must be used.

SYSTEM COMPONENTS

The simulation procedure used in the FoDEWS is the Versatile Soil Moisture Budget (Baier and Robertson 1966). To apply the model it was assumed that one soil type is a good indication of soil moisture conditions throughout the region. Differences in soil types can be minimized if estimates are normalized to similar estimates for historical conditions (Dyer *et al.* Dec. 1981). A clay loam, which can hold 200 mm of plant available water, was taken as a benchmark soil. The budget was run with three soil layers, representing 120 cm of soil. Extraction of soil water was based on a generalized domestic perennial forage as distinct from soil water use by a typical annual grain crop. The system is not sensitive to differences in domestic perennial forage species but its correlation to native pasture species has not been established. This model takes into account the aforementioned previous events and rela-

tionships. A sub-model for water storage in the snowpack, recently added to an updated version of the model (Baier *et al.* 1979), is particularly important to this application.

Figure 1 depicts a time line for the projection procedure. This diagram shows the passage of time (left to right) and the availability of weather data and model estimates for past, present and future conditions. The left vertical line represents the update, or the date of transition from current year records to historical data when estimating future conditions. The vertical line on the right represents the target date. This approach is similar to that of Williams and Robertson (1965) and Garron (1980) in predicting small grain cereal yields, except that monthly long-term normals are replaced with actual historical periods. To realistically estimate soil moisture, the inherent day-to-day variability of the weather is essential. This variability is lost when daily records are averaged. Each line at the bottom represents a year for which the simulation procedure gave a near average estimate for May 31. These years were selected from 30 years of estimates for May 31, based on the closeness of the estimates to exceeding exactly half of the 30 estimates (or the mode) at each site. The chances for an estimate in a random year falling below the average of the 3 selected years at each site is therefore 50%. The path A to B to C to D represents the simulation time line in the FoDEWS. An example of a system which gives monitoring rather than projected information is the Soil Moisture Evaluation Project (SMEP) series of reports for soil moisture reserves under a cereal crop (Edey 1980). That system is represented simply by A to B.

PROCEDURE

The system's operation plan is shown in Figure 2. First, data of weather observations at each prairie site are collected and stored. After reaching Ottawa, these data are put in computer files which can be used to drive the simulation model. An overwrite procedure replaces each historical daily record with new data as the daily observations arrive. This fulfills the update step shown in Figure 1. The combination of historical and current weather records is stored as new files that represent synthetic years.

These synthetic years are then analyzed by the soil moisture budget that uses fixed, standardized control data. The soil moisture estimates for all 3 years at each site are averaged and, following the right branch, are expressed as percentages of normal. Back on the main branch, frequency class contours are drawn on the map of non-normalized projections using threshold moisture levels for five frequencies of occurrence. These two maps are attached to a brief verbal summary to form a biweekly or monthly report.

Considerable similarity exists between the drought risk areas of the two types of map. The frequency based map gives a more objective representation of drought severity (Dyer *et al.* Dec. 1981) but both ways were used, since many users are familiar with percentage of normal representation. The percentage of normal drought severity classes were based on moisture reserve levels that were below 60% of normal, 60 - 80%, 80 - 100% and above normal.

The selected threshold levels of moisture for selected frequencies were derived by applying the simulation procedure to 30 years, sorting the May 31 estimates into ascending order to give an accumulative frequency distribution and extracting thresholds from these distributions. The classes of drought severity based on frequency of occurrence included moisture reserve levels below the driest year of 5, the driest year of 3, the driest year of 2, above the driest year of 2 and above the driest 2 of 3 years. The frequency distributions were derived in a previous study of the relationship between frequencies (or probabilities) and long-term normals (Dyer *et al.* Dec. 1981). The selected years for the overwrite procedure (Figure 2) were also taken from these distributions.

PERFORMANCE EVALUATION

The value of an early warning system for drought risk depends on the correlation between early projected drought areas with final May 31 estimated areas. We therefore evaluated the prediction accuracy by comparing sites falling in each drought severity class in the early projections with the severity classes that those sites were assigned to in the final estimates. Computer estimates made after May 31 are no longer considered to be projections, since they are based entirely on the current year weather data.

We tested the potential ability to have predicted 4 past years – 1976, 1977, 1980 and 1981 – as well as the performance for 1982. The bars in Figure 3 show the number of site-years falling in each drought class for each projection date. The first bar is the number of final counts (site-years in each family), the second is the number that were projected, the third is the number that were projected correctly and the fourth is the number that were projected within one severity class. The mathematical notations for drought severity classes in Figure 3 (i.e., or n/m) are interpreted as moisture reserves that are below or above the driest n out of m years.

RESULTS

For the moderately severe drought levels (below the driest year in 3 and in 2), early projections were in the correct class in about half of the 150 site-year cases considered, but were within one class in about four out of five cases (Figure 3). The variability in the severity of drought as well as in its spatial occurrence is due to the relative terms at each site. Although these results are encouraging, we were overly pessimistic in

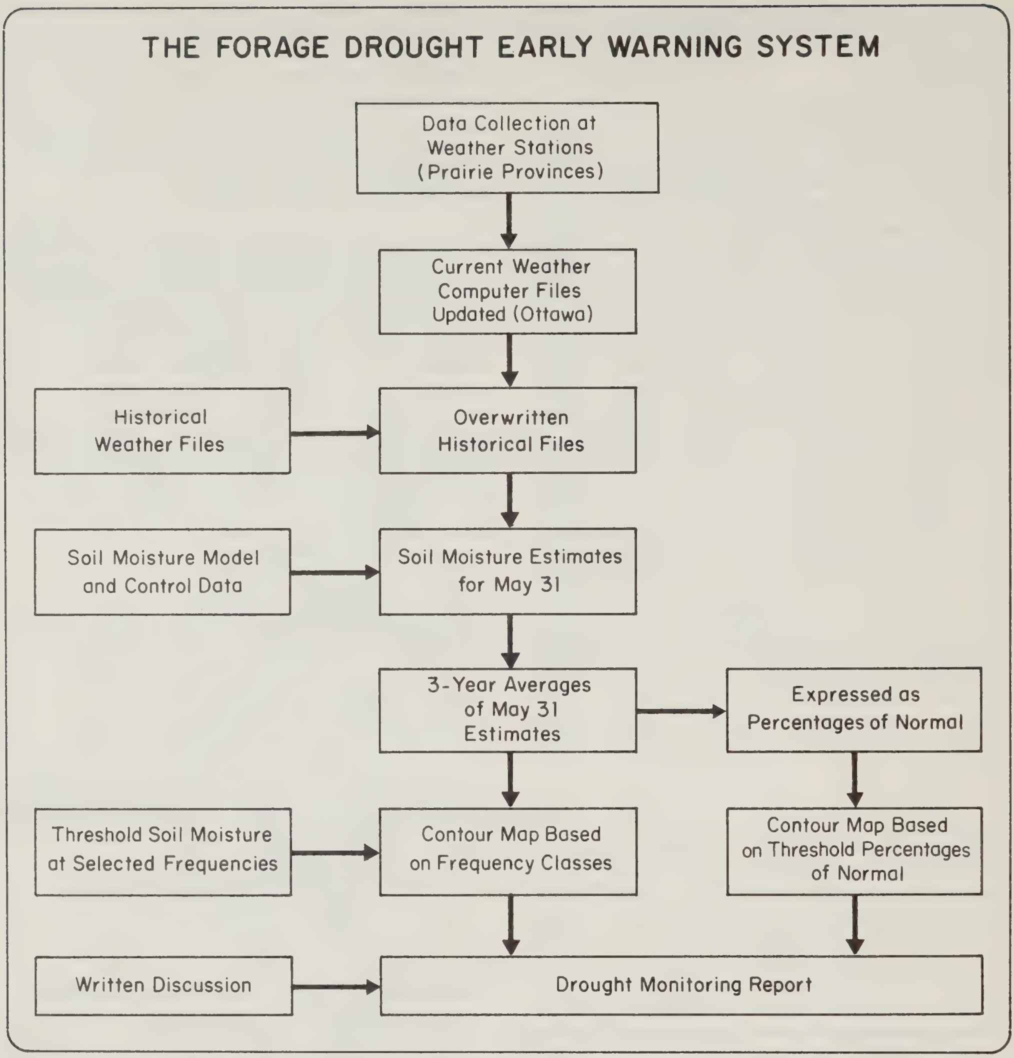


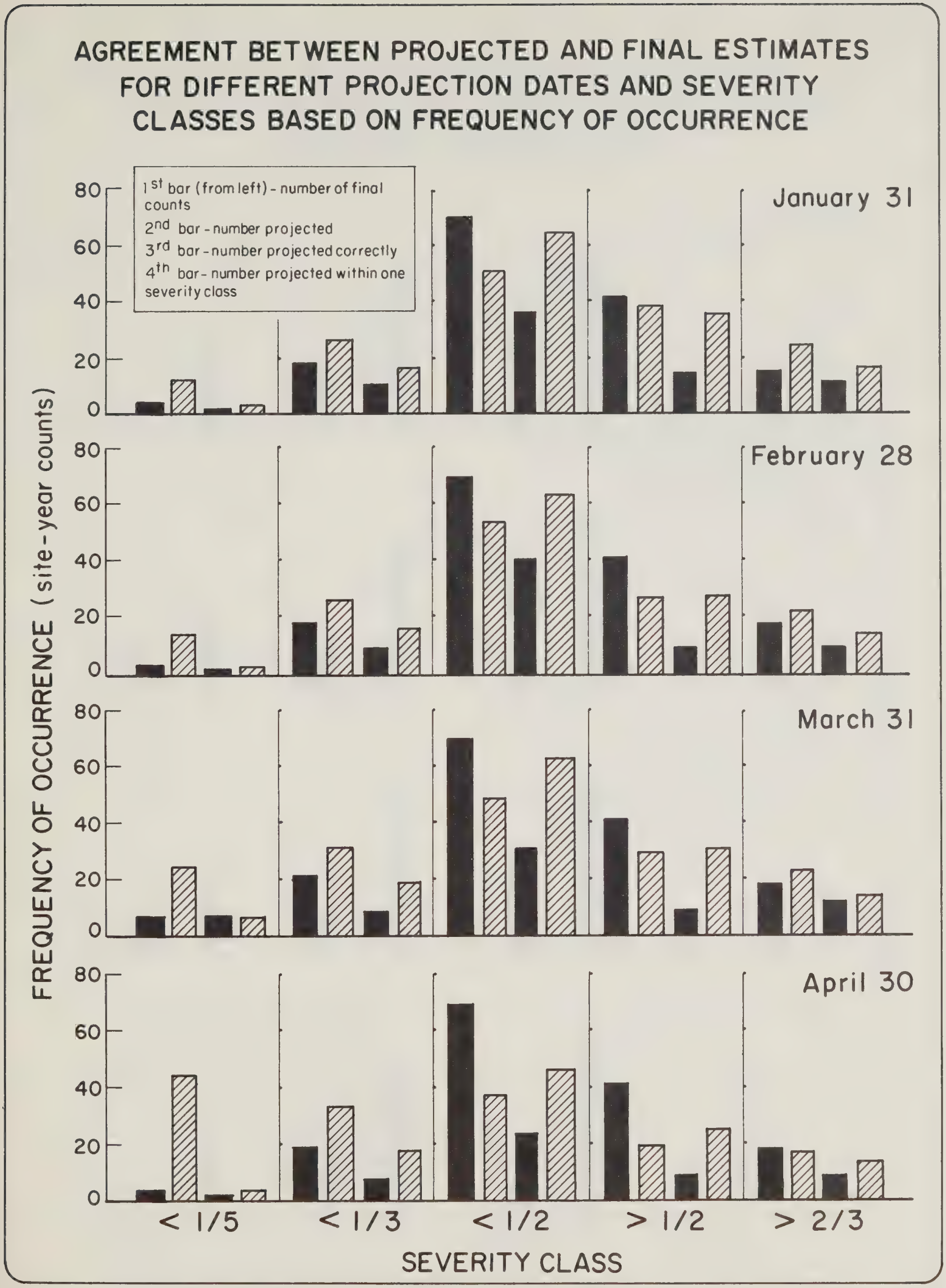
Figure 2

projecting the severest class, that is, drier than the driest year in 5. We also became more pessimistic for the April and May projections.

Similar results are evident in the percentage of normal severity class distributions shown in Figure 4. Pessimism in the below 60% of normal severity is evident, particularly for April.

The year-to-year changes in drought can be seen by examining the 5 test years individually (Figure 5). Similarity between the early projections and final estimates is evident. Since only the driest year in 3 severity class is illustrated, projections can be easily compared with the final estimates. This represents a moderately severe level of drought. (In a typical drought report, the user would see all severity classes.)

In 1976, northern Manitoba and Alberta were drought zones. We were successful in predicting the northern Manitoba zone. In 1977, we predicted extensive drought, most of which was alleviated by heavy May rainfall. In 1980, extensive drought was apparent in all three provinces and there was good correlation between projected and final drought areas. In 1981, we were successful in predicting drought in southern Saskatchewan (Regina-Moose Jaw) but unsuccessful at two other sites. In 1982, our predictions for the Alberta-Saskatchewan border area were correct but we failed



AGREEMENT BETWEEN PROJECTED AND FINAL ESTIMATES FOR DIFFERENT PROJECTION DATES AND SEVERITY CLASSES BASED ON FREQUENCY OF OCCURRENCE
1st bar (from left) - number of final counts
2nd bar - number projected
3rd bar - number projected correctly
4th bar - number projected within one severity class
January 31
February 28
March 31
April 30
FREQUENCY OF OCCURRENCE (site-year counts)
80
60
40
20
0
< 1/5
< 1/3
< 1/2
> 1/2
> 2/3
SEVERITY CLASS

Figure 3

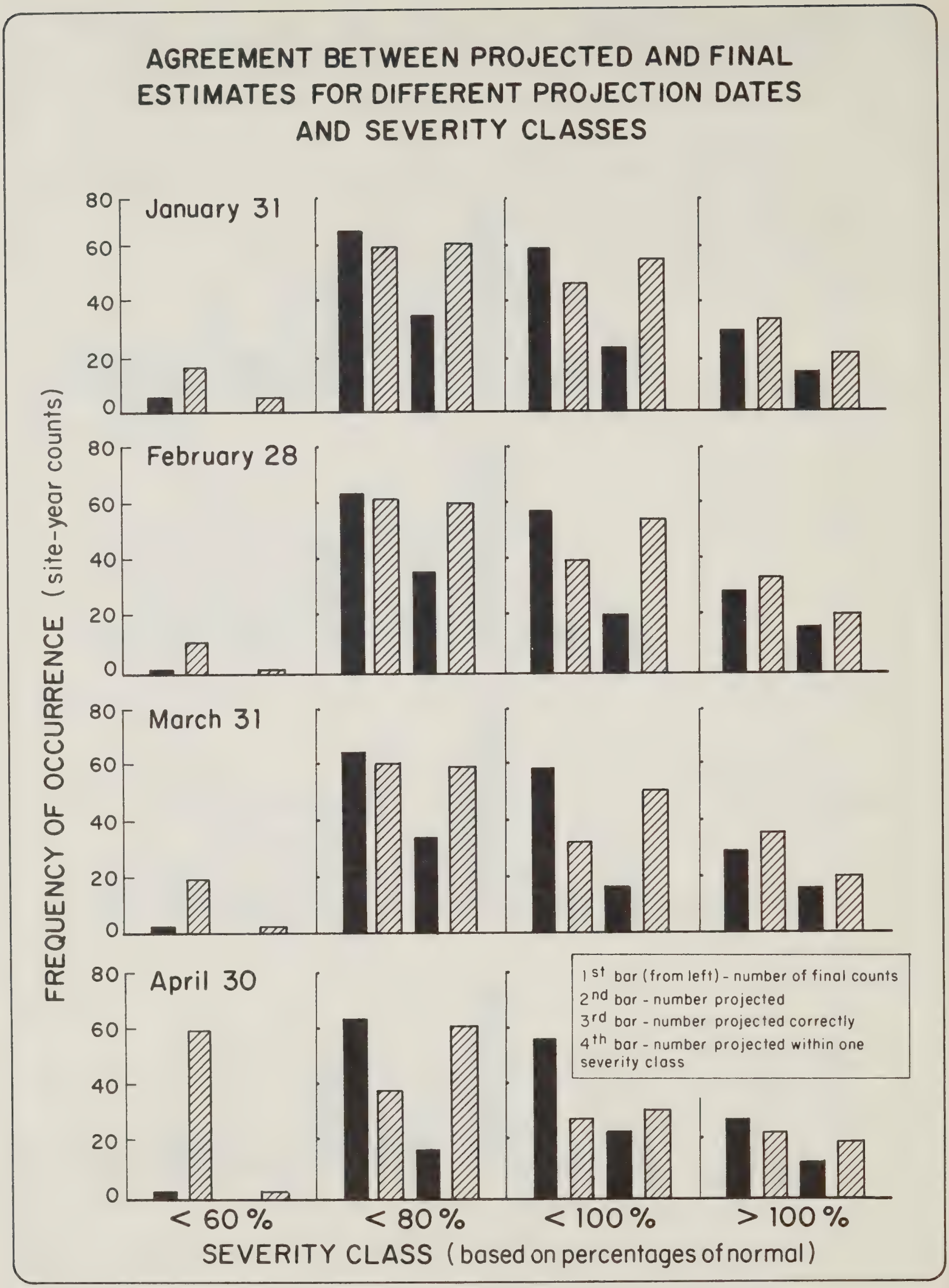

AGREEMENT BETWEEN PROJECTED AND FINAL ESTIMATES FOR DIFFERENT PROJECTION DATES AND SEVERITY CLASSES
January 31
February 28
March 31
April 30
FREQUENCY OF OCCURRENCE (site-year counts)
0
20
40
60
80
1st bar (from left) - number of final counts
2nd bar - number projected
3rd bar - number projected correctly
4th bar - number projected within one severity class
< 60 %
< 80 %
< 100 %
> 100 %
SEVERITY CLASS (based on percentages of normal)

Figure 4

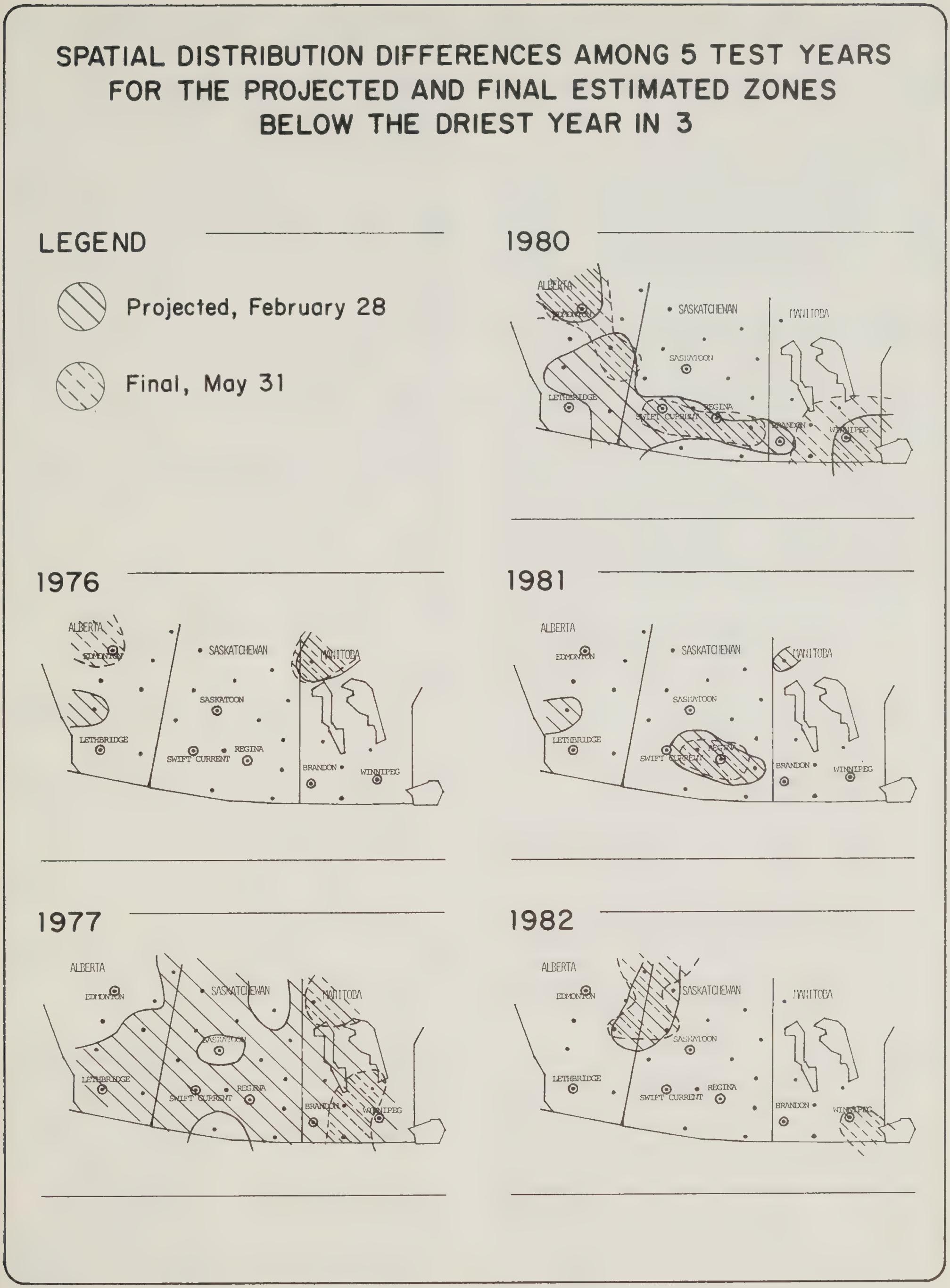

SPATIAL DISTRIBUTION DIFFERENCES AMONG 5 TEST YEARS
FOR THE PROJECTED AND FINAL ESTIMATED ZONES
BELOW THE DRIEST YEAR IN 3
LEGEND
Projected, February 28
Final, May 31
1976
1977
1980
1981
1982
ALBERTA
EDMONTON
SASKATCHEWAN
MANITOBA
SASKATOON
LETHBRIDGE
SWIFT CURRENT
REGINA
BRANDON
WINNIPEG

Figure 5

to forecast the area of drought appearing around Winnipeg. As well as illustrating the yearly variation in the areas affected by drought, these maps show that projections are reasonably sensitive to this variation.

DISCUSSION

The frequency of occurrence criteria for drought are interpreted as the return periods of those conditions for which they were defined. When financial compensation is made to farmers in one season, we should anticipate that farmers will expect to receive assistance if the same conditions occur again. Choosing the criterion of 1 year in 3 means that moisture reserves will be below the threshold level in a third of the years. We can therefore expect requests for payments at that long-term average rate over a broad area.

The projection accuracy, on the other hand, is an indication of the chances of having to make payments in any given year. To put the frequency and accuracy values into perspective, we can consider the case where no analytical projections are available. With random guessing, an area has a 33% chance of being below the driest year in 3 and a 50% chance of being below both the driest year in 2 and 3 years. Whereas once that area has been projected to be below the driest year in 3, the chances for realizing driest year in 3 conditions are raised to approximately 60 - 65% (including the possibility of being below the driest year in 5). An area projected to be below the driest year in 2 would have about a 25% chance of being below the driest year in 3. If projected to be above the driest year in 2, the chances for driest year in 3 levels drop to approximately 15%. In the limited number of cases that the system projects driest year in 5 levels, the chances of the driest year in 3 are approximately 80 - 90%.

These comparisons illustrate that the projections can both quantify and reduce the risks involved in preseason decision making. Without these projections, such decisions would not be totally random guesses, because weather data interpretations for other applications are available. But a great deal of uncertainty, particularly during the winter months, would remain. Decision makers would have to rely on verbal reports and subjective interpretation of other information which can often be conflicting or misleading.

APPLICATION

The economic value of the early warning projections depends on the importance of decisions which may be based on them, as well as the accuracy. The lead time provided allows drought assistance programs to be put in place quickly. Since the areas affected by drought vary so much from year to year, the size and location of areas most likely to suffer drought, and likely to require assistance, is important information.

Assistance programs can involve large amounts of money for payments. With increased confidence that assistance will be needed, the cash for payments can be more easily committed.

The neef for an *ad hoc* assistance scheme, such as the beef herd maintenance program in 1980, will be less likely as crop insurance schemes for forages become established. A pre-season monitoring system such as FoDEWS will still be of interest because it will assist in alerting decision makers to cash flow requirements under a forage crop insurance program.

Timely payments can make assistance or crop insurance payments more effective in stabilizing farm income. Cash payments which reach farmers soon after they have suffered crop losses help maintain required cash flow levels. This is particularly true of beef producers who depend on a spring pasture crop to maintain herd sizes. Early warning of the probable extent of drought helps provide lead time to ensure that the necessary cash is available to make timely payments. Lead time is particularly important for other drought proofing measures, such as helping producers to find alternate feed sources.

Weather-based computer information systems such as FoDEWS are objective, unbiased and timely. Operational expenses of FoDEWS are relative to the cost of administering assistance or crop insurance payments. Improvements to the system, such as the inclusion of satellite or additional weather data to increase the spatial resolution, are being considered. But FoDEWS has already demonstrated that it can play a useful role in the prairies' beef production industry.

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A review of the Farm Improvement Loans Act

The Canadian government introduced the Farm Improvement Loans Act (FILA) in 1945 to encourage chartered banks and other lenders to provide short and intermediate term credit to Canadian farm operators. This guaranteed loan program rapidly became popular with both lenders and borrowers, and by 1965 it had captured 17% of the short and intermediate term credit market based upon amounts outstanding.

Since 1965, however, FILA has lost considerable ground relative to other sources of short and intermediate term farm credit. In 1981, based upon amounts outstanding, the program accounted for only 5.5% of the total short and intermediate term credit market.

This decline in FILA's importance is attributed to changing attitudes of chartered banks, the Bank Act of 1967, the expansion of agricultural lending programs administered by provincial governments and the growing demand, particularly in recent years, for refinancing and debt consolidation loans which are ineligible under FILA.

S.C. Lok

INTRODUCTION

Because of recent high interest rates and a rise in farm bankruptcies, the provision of credit to agriculture in Canada has become a major concern to producer organizations, commercial lenders and governments. The Farm Improvement Loans Act (FILA), now administered by Agriculture Canada, has assisted in the provision of short and intermediate term loans to producers since 1945. The authority of the minister of agriculture to guarantee new loans under the act ends in 1983, unless extended. This paper examines the evolution of the act and seeks to explain the significant decline in the number of FILA loans extended annually.

BACKGROUND

FILA was established in 1945 to assist farm operators in adjusting to the change in economic focus which was expected to occur in Canada following World War II.

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The legacy of the depression followed by concomitant shortages of manpower, materials and machinery after the war signaled the need to retool Canadian farms.

Before 1945, farm equipment and machinery had been financed predominantly by equipment dealers and material suppliers. Because of the high cost and inflexibility of these financing sources and the magnitude of capital investment which was expected to occur, other sources of agricultural credit were needed.

The chartered banks, thus far, had not tapped the farm credit market. This situation was due partly to the banks' primarily urban focus and their reluctance to enter into term lending. Also, because of the unsatisfactory experiences with the repayment of farm operating loans during the depression, the banks had a psychological barrier against further penetration into the agricultural credit market (Finance Canada).

FILA was established initially for 3 years. Its purpose was to encourage chartered banks to extend short and intermediate term loans for "the improvement and development of farms and for the improvement of living conditions thereon" (Agriculture Canada). Under the act, the federal minister of finance would guarantee loan repayment of a maximum of $250 million in aggregate principal for 3 years.

To qualify for a loan, a borrower had to possess a farm and his primary occupation had to be farming. The maximum amount of loans outstanding per borrower was set at $3000 for a term of up to 10 years at a fixed rate of 5%. Eligible purposes for loans included agricultural implements; land and other physical farm improvements; construction, alteration and renovation of farm buildings; livestock; and farmstead home appliances.

Since its inception, FILA has been amended 18 times (Appendix). These amendments have extended it for 11 additional 3-year periods and have broadened the purposes for which loans may be granted. Farm operators may now borrow up to $100 000 under the act from chartered banks, credit unions, trust companies, Alberta Treasury branches and other financial institutions designated as lenders. Repayment schedules are still for a maximum of 10 years, with the exception of loans for additional land, which may be for a maximum of 15.

The method of calculating the maximum interest rates chargeable under FILA, originally fixed at 5%, was changed in 1968. Between 1968 and 1978, rates remained fixed for the term of the loan but were adjusted twice a year according to yields of selected government bonds. Since 1978, the maximum interest rate chargeable has floated at bank prime plus 1%.

Administration of the FILA has been the responsibility of Agriculture Canada's Farm Development Division since April 1979.

TABLE 1. FILA LOANS, BANK LOANS, AND ALL SOURCES OF INTERMEDIATE TERM AGRICULTURAL CREDIT EXTENDED[1]

	FILA loans extended	Total value of FILA loans extended	Intermediate term agricultural bank loans extended (including FILA loans)	FILA loans extended as a percentage of intermediate term agricultural bank loans extended	Total intermediate agricultural credit extended	FILA loans as a percentage of total intermediate agricultural credit extended
	no.	$ million	$ million	%	$ million	%
1946-50[2]	33 850	33.3	33.3	100	–	–
1951-55[2]	72 333	82.5	82.5	100	–	–
1956-60[2]	65 526	86.2	86.2	100	–	–
1961-65[2]	78 786	143.1	143.1	100	317.8	45.0
1966-70[2]	52 117	140.4	165.4	84.8	422.6	33.2
1971	46 790	147.8	202.8	72.8	528.4	27.9
1972	53 591	181.9	246.9	73.6	701.3	25.9
1973	58 267	231.8	360.8	64.2	840.6	27.5
1974	33 685	167.6	364.6	45.9	917.4	18.2
1975	29 928	209.8	421.8	49.7	1199.1	17.4
1976	20 721	164.3	514.3	31.9	1605.9	10.2
1977	17 086	130.2	649.7	20.0	1976.9	6.5
1978	24 644	228.4	898.4	25.4	2303.9	9.9
1979	25 174	264.4	741.9	35.6	2006.8	13.2
1980	19 319	220.2	1143.3	19.3	2459.7	8.9
1981	15 085	184.2	–	–	–	–

[1] In addition to the banks, intermediate term credit is also supplied to agriculture by supply companies; credit unions, insurance, trust and loan companies; private individuals; and Alberta Treasury branches.

[2] Figures in these rows are 5-year annual averages.

Sources: FILA annual reports; R.S. Rust, formerly with Agriculture Canada; and W.D. Jones, Agriculture Canada.

PERFORMANCE: 1946-65

Between 1945 and 1965, the number and the amount of loans extended annually under FILA increased rapidly. Between 1946 and 1950, an average of 34 000 loans amounting to $33.3 million were guaranteed each year. By 1960-65, the average number of loans extended each year had increased 130% to 79 000, and the average annual amount of all loans extended between 1960 and 1965 had risen 330% to $143.1 million (Table 1).

Trends are similar for amounts outstanding. Between 1946-50 and 1961-65, the average annual value of FILA loans outstanding increased nearly 700% from $33 million to $259 million (Table 2). Approximately 80% of the loans made during this period were for the purchase of farm implements such as tracators, trucks, tillage equipment, milking machines and consumer appliances (Tables 3, 4 and 5).

Between 70-80% of all loans were made in Alberta, Saskatchewan and Manitoba; Ontario accounted for 10-15% and Quebec 10%. The Atlantic Provinces and B.C. each accounted for approximately 3% (Table 6).

The number of claims paid under the act averaged less than 100 a year between 1945 and 1953, and the amount of claims paid averaged less than $20 000 annually. From 1953 to 1955, both the number and amount of claims increased rapidly. Between 1955 and 1965, these figures were relatively stable. An average of 238 claims totaling $1.58 000 were paid each year (Agriculture Canada).

Until the mid-1960s, FILA was an unqualified success. It was popular with farmers. On the average, about 79 000 loans were extended each year. It also encouraged the banks to enter the field of intermediate farm credit and, up until approximately 1965 it was virtually the only type of intermediate term agricultural loan offered by them. With the exception of the Veterans' Land Act administered by the federal Department of Veterans' Affairs, and a few specific purpose loans offered by provincial governments, FILA loans were the only government supported source of intermediate term credit available to farmers in Canada. At this time, FILA loans held a 17% share of the combined short and intermediate term agricultural credit market, based upon loans outstanding.

TABLE 2. FILA LOANS, AGRICULTURAL BANK LOANS, AND ALL SOURCES OF INTERMEDIATE TERM AGRICULTURAL CREDIT OUTSTANDING[1]

	Total amount of FILA loans outstanding	Total agricultural bank loans outstanding (including FILA loans)	FILA loans outstanding as a percentage of total agricultural bank loans outstanding	Total short and intermediate term agricultural credit outstanding	FILA loans outstanding as a percentage of total short and intermediate term agricultural credit outstanding
	$ million	$ million	%	$ million	%
1946-50[2]	33	172	19.1	302[3]	10.9
1951-55[2]	126	337	37.3	514[3]	24.5
1956-60[2]	151	387	39.0	870[3]	17.3
1961-65[2]	259	636	40.7	1552	16.6
1966-70[2]	363	1028	35.3	2432	14.9
1971	331	1325	24.9	2796	11.8
1972	371	1492	24.8	3167	11.7
1973	453	1868	24.2	3739	12.1
1974	458	2162	21.1	4426	10.3
1975	485	2583	18.7	5365	9.0
1976	476	3170	15.0	6193	7.7
1977	427	3765	11.3	7063	6.0
1978	471	4650	10.1	7769	6.1
1979	548	5968	9.1	9148	5.9
1980	539	6928	7.7	8694	6.2
1981	543	7377	7.3	9801[3]	5.5

[1] In addition to banks, the major sources of short and intermediate term credit are supply companies; credit unions, insurance, trust and loan companies; private individuals; cooperatives; and Alberta Treasury branches.

[2] Figures in these rows are 5-year annual averages.

[3] Data estimated using a logarithmic regression analysis.

Sources: FILA annual reports, 1946-81; Bank of Canada reviews, 1946-81; and Agriculture Canada estimates.

PERFORMANCE: 1966-81

Between 1965 and 1981, the number of FILA loans extended annually dropped fourfold from about 79 000 to 15 000 (Table 1). While the annual amount extended continued to rise, from $143 million in 1965 to $265 million in 1979, the average annual rate of increase shrank significantly from 140% a year between 1946 and 1965 to only 8% a year between 1966 and 1980. These latter increases ran only slightly above the average annual rate of inflation for the same period (6.6%).

Between 1966-70 and 1981, amounts outstanding under FILA increased sporadically by a total of 50% from $363 million to $543 million. This figure is small relative to increases in total Canadian short and intermediate term agricultural credit outstanding during this period, which rose 303% from $2.4 billion to $9.8 billion (Table 2).

In 1980, about 9% of the value of intermediate term loans extended for agricultural purposes in Canada were guaranteed under the act. Seventy percent ($154 million) of this was divided approximately equally between Alberta and Saskatchewan (Table 6). Manitoba, Ontario and British Columbia were also significant users of the program and shared a further 26% ($57 million) in a ratio of approximately 2:1:1. The Atlantic Provinces used 3% ($6 million) and Quebec 1% ($2 million).

Approximately 70% of all FILA loans in 1981 were used for farm implement purchases, a figure which has remained relatively constant (Table 4). Other uses (in order of importance) were for the construction and repair of farm buildings, livestock purchases, additional land purchases and land development.

Claims paid under the act have varied significantly during the last decade. In 1971, $726 000 was paid to lenders for losses on defaulted loans. This figure represented 0.2% of FILA loans outstanding in that year (Table 8). By 1976, claims from lenders had dropped to $199 700, 0.04% of the $476 million outstanding under the act that year. Claims increased in the latter half of the 1970s and in 1981, equaling $514 500, or 0.1% of all FILA loans outstanding. This latter increase is attributed to financial problems now facing the agricultural industry.

TABLE 3. FILA LOANS EXTENDED ACCORDING TO PURPOSE OF LOAN, 1946-1981, ABSOLUTE VALUES[1]

	Implement purchases		Land clearing, breaking, fencing, drainage, irrigation and land development		Construction, repair and alterations of farm homes and buildings		Livestock purchases		Additional land purchases		Repair and overhaul of implements and equipment		Total	
	no.	$ thous.	no.	$ thous.	no.	$ thous.	no.	$ thous.	no.	$ thous.	no.	$ thous.	no.	$ thous.
1946-50[2]	29 200	29 900	1 900	800	1 700	1 900	1 000	700	–	–	–	–	33 800	33 300
1951-55[2]	63 300	73 500	2 000	1 500	3 500	4 500	3 600	3 000	–	–	–	–	72 400	82 500
1956-60[2]	52 700	69 500	1 900	1 700	5 000	8 500	5 900	6 500	–	–	–	–	65 500	86 200
1961-65[2]	57 600	105 000	4 100	4 800	8 000	20 000	87 000	13 200	–	–	–	–	78 400	143 000
1966-70[2]	37 700	98 800	3 600	7 800	5 200	20 900	5 000	12 000	–	–	–	–	51 500	139 500
1971-75[2]	33 800	125 500	2 300	8 300	3 500	19 900	3 400	11 600	1 700	19 600	–	–	44 700	184 900
1976	17 500	115 300	1 000	6 900	1 600	17 500	650	3 200	650	16 800	30	76	21 500	159 900
1977	14 700	98 000	1 000	6 500	1 500	14 100	700	3 200	400	10 400	31	60	18 000	132 200
1978	21 300	170 400	1 100	8 300	2 000	22 400	1 000	6 900	500	17 500	31	60	26 000	225 600
1979	21 000	192 800	1 200	10 500	2 200	27 500	1 500	14 800	500	16 900	43	200	26 700	262 700
1980	15 400	153 300	1 200	11 900	1 600	22 200	1 600	16 800	400	16 000	44	100	20 300	220 200
1981	11 700	123 700	1 000	11 900	1 400	20 000	1 300	13 700	300	14 700	64	300	16 000	184 200

[1] All figures have been rounded.

[2] Figures in these rows are 5-year annual averages.

Source: FILA annual reports, 1946-81.

TABLE 4. FILA LOANS EXTENDED BY PURPOSE OF LOAN, 1946-1981, PROPORTIONAL VALUES[1]

	Implement purchases		Land clearing, breaking, fencing, drainage, irrigation and land development		Construction, repair and alterations of farm homes and buildings		Livestock purchases		Additional land purchases		Repair and overhaul of implements and equipment		Total	
	no.[2]	value[3]	no.	value	no.	value	no.	value	no.	value	no.	value	no.	value
1946-50	86	90	6	2	5	6	3	2	—	—	—	—	100	100
1951-55	87	89	3	2	5	5	5	4	—	—	—	—	100	100
1956-60	80	80	3	2	8	10	9	8	—	—	—	—	100	100
1961-65	73	73	5	3	10	14	11	9	—	—	—	—	100	100
1966-70	73	71	7	6	10	15	10	9	—	—	—	—	100	100
1971-75	76	68	5	4	8	11	8	6	4	11	—	—	100	100
1976	81	72	5	4	7	11	3	2	3	11	0.1	0.04	100	100
1977	82	74	6	5	8	11	4	2	2	8	0.2	0.04	100	100
1978	82	75	4	4	8	10	4	3	2	8	0.1	0.02	100	100
1979	79	73	4	4	8	10	6	6	2	6	0.2	0.10	100	100
1980	76	70	6	5	8	10	8	8	2	7	0.2	0.04	100	100
1981	73	67	6	6	9	11	8	7	2	8	0.3	0.20	100	100

[1] Figures may not add to 100% because of rounding.
[2] Percentage of the total number of loans extended.
[3] Percentage of the total value of loans extended.

Source: Table 3.

TABLE 5. AVERAGE VALUE OF FILA LOANS EXTENDED BY PURPOSE OF LOAN

	Implement purchases	Land clearing, breaking, fencing, drainage, irrigation and land development	Construction, repair and alterations of farm homes and buildings	Livestock purchases	Additional land purchases	Repair and overhaul of implements and equipment	All Loans
				dollars			
1946-50	1 020	420	1 120	700	—	—	990
1951-55	1 160	750	1 290	830	—	—	1 140
1956-60	1 320	900	1 700	1 100	—	—	1 320
1961-65	1 820	1 170	2 500	1 520	—	—	1 820
1966-70	2 620	2 170	4 020	2 400	—	—	2 710
1971-75	3 230	3 600	5 690	3 410	11 530	—	4 140
1976	6 590	6 900	10 940	4 920	25 850	2 530	7 440
1977	6 670	6 500	9 400	4 570	26 000	1 940	7 344
1978	8 000	7 550	11 200	6 900	35 000	1 940	8 677
1979	9 180	8 750	12 500	9 870	33 800	4 650	9 840
1980	9 950	9 920	13 880	10 500	40 000	2 270	10 850
1981	10 600	11 900	14 300	10 500	49 000	4 700	11 500

Source: Table 3.

TABLE 6. FILA LOANS EXTENDED BY PROVINCE, 1945-80

	B.C.		Alta.		Sask.		Man.		Ont.		Que.		Atlantic Provinces		Canada	
	no.	amount[1]	no.	amount	no.	amount	no.	amount	no.	amount	no.	amount	no.	amount	no.	amount
1946-50[2]	960	0.9	11 120	10.7	11 700	11.8	4 900	4.8	3 600	3.6	1 100	1.0	470	0.4	33 800	33.3
1951-55[2]	2 200	2.3	18 800	21.5	21 200	25.6	8 500	9.3	11 300	12.7	7 100	8.0	3 200	3.0	72 400	82.5
1956-60[2]	1 800	2.5	16 100	20.8	16 400	21.2	7 100	9.0	11 700	16.2	9 900	13.4	2 600	3.0	65 500	86.2
1961-65[2]	2 300	4.9	22 500	40.4	22 400	40.8	9 800	17.4	14 800	28.0	4 380	8.0	2 300	3.6	78 500	143.1
1966-70[2]	1 900	6.1	16 800	44.3	15 300	39.9	6 000	16.5	10 200	29.1	340	1.3	1 520	3.7	52 200	140.4
1971-75[2]	1 600	6.7	14 200	56.1	15 000	63.9	4 800	20.3	7 200	30.7	200	1.2	1 600	5.8	44 700	184.9
1976	900	6.2	7 700	56.0	7 100	55.6	2 800	20.4	2 100	16.7	80	0.7	731	4.2	21 500	159.8
1977	800	5.9	5 900	42.4	6 400	46.3	2 700	18.4	1 600	13.0	86	0.6	880	5.5	18 300	132.2
1978	800	7.5	9 400	84.9	8 400	77.8	3 500	30.0	1 600	18.5	71	1.3	700	5.6	24 400	225.6
1979	1 000	13.7	10 000	102.9	8 400	85.9	3 500	33.4	1 400	18.9	50	0.9	800	6.9	25 200	262.7
1980	1 100	16.9	7 000	74.6	7 000	79.2	2 500	25.2	1 200	16.1	75	2.0	670	6.0	19 300	220.2
1981	900	15.4	4 900	57.4	5 700	68.8	2 000	21.4	800	12.4	100	3.4	500	5.4	15 100	184.2

[1] Amounts are in millions of dollars.

[2] These figures are 5-year annual averages.

Source: FILA annual reports, 1945-81.

TABLE 7. FILA LOANS EXTENDED BY COMMERCIAL SOURCE, 1970-80

	Bank of Commerce	Royal Bank	Bank of Montreal	Bank of Nova Scotia	Toronto-Dominion	National Bank[1]	Bank of British Columbia	Total chartered banks[2]	Other sources[3]	Total, all sources
	thousands of dollars									
1970	40 900	18 500	23 000	10 300	9 000	900	–	102 600	300	102 900
1971	56 100	26 300	34 300	12 700	15 300	1 300	–	146 000	1 400	147 400
1972	70 000	27 200	40 100	19 300	19 500	1 800	–	177 900	3 200	181 100
1973	78 700	35 900	48 600	28 600	30 200	1 700	–	223 700	6 500	230 200
1974	34 400	32 500	30 600	29 900	30 600	1 000	4	159 000	3 900	162 900
1975	22 800	42 700	25 800	46 300	49 500	1 800	–	188 900	13 900	202 800
1976	31 400	14 200	19 200	28 800	53 000	1 200	30	147 800	12 100	159 900
1977	39 400	1 300	10 500	27 800	41 900	1 800	21	122 700	9 500	132 200
1978	98 800	2 600	9 300	40 500	59 000	2 800	64	213 000	12 600	225 700
1979	128 300	7 800	14 600	42 400	59 500	2 600	300	255 400	7 300	262 700
1980	101 700	16 900	16 700	32 200	45 500	2 000	89	215 000	5 200	220 200
1981	79 600	16 300	16 200	29 100	37 400	1 200	172	180 000	4 200	184 200

[1] Previously split between Banque Canadienne Nationale and Provincial Bank until merged in 1980.

[2] Does not include Continental or Unity Banks with loans totaling $68 600 in 1981.

[3] Other sources include Alberta Treasury branches (as of 1974), trust companies and credit unions.

Source: FILA annual reports, 1970-81.

TABLE 8. CLAIMS PAID UNDER FILA

	Loans outstanding	Claims paid	Claims as a percentage of loans outstanding
	thousands of dollars		%
1971	331 000	726.6	0.21
1972	371 000	657.0	0.17
1973	453 000	628.7	0.13
1974	458 000	503.6	0.11
1975	485 000	290.7	0.05
1976	476 000	199.7	0.04
1977	427 000	296.0	0.06
1978	471 000	452.1	0.09
1979	458 000	354.0	0.06
1980	539 000	435.8	0.08
1981	513 000	514.5	0.10

Source: FILA annual reports.

ANALYSIS

FILA greatly expanded the number of sources and the amount of intermediate credit available to farms at a time when it was needed by encouraging the chartered banks and other commercial lending institutions to service the agricultural sector at a level on par with the credit markets of other sectors of the economy. The act was able to achieve its objectives at relatively low cost and risk to lenders and the federal government. Since 1945, FILA loans have financed intermediate term investments of $4.6 billion on Canadian farms at a cost (excluding administration) of $6.6 million in net claims (Agriculture Canada), that is, $0.15 for each $100 lent.

Why then has FILA's intermediate term credit market share eroded from 45% during the early 1960s, based on amounts extended annually, to less than 9% in 1980? Several interrelated factors can help explain this trend.

Between 1946 and 1956, the banks' prime rates were stable at 4.5%, while the maximum rate chargeable for FILA loans was fixed at 5.0%. At the end of the first quarter of 1956, the bank prime rate rose to 5.0% and then continued to climb to 7.0% by the third quarter of 1968. Coupled with this climb was a period of tight money between 1967 and 1968 which restricted loans to all sectors of the economy. The banks, therefore, became increasingly reluctant to lend at 5% under FILA as the difference between the maximum rate chargeable under the act and bank prime rates increased. The maximum rate chargeable under FILA was subsequently adjusted in 1968, leaving one to expect an increase in FILA lending activity.

In 1967, however, the federal government passed a new bank act. The Bank Act of 1967 gave the chartered banks the right to engage in mortgage financing. The act also eliminated the 6% ceiling on loan rates (Hopkins). As a result of these changes, the chartered banks were quick to respond to the demand for farm credit. Confident in their ability to service agriculture because of their experience with agriculture credit markets through FILA, the Royal Bank and the Bank of Montreal set up their own agricultural lending programs in 1968 which offered short, intermediate and long term loans at competitive rates. They were followed by the Canadian Imperial Bank of Commerce in 1969, the Toronto-Dominion Bank in 1971 and the Bank of Nova Scotia which set up its Farm Services Department in 1974. By 1975 (within 8 years of the new bank act), the chartered banks had captured 18% of the intermediate term agricultural credit market with their own programs, leaving FILA with 17% based upon amounts extended per year. In 1980 (Table 1), the market share of the chartered banks' own programs had risen to 38% ($928 million), whereas FILA's market share had dwindled to 9% ($220 million).

To qualify under FILA for interest rates of prime plus 1% and the government guarantee, borrowers must now meet the lending institution's normal lending criteria. This fact partly explains why the costs of running FILA have been so low. Under their own programs the banks offer rates of approximately prime plus 1.5%. Many lenders believe that the reduced risk associated with a FILA loan is not sufficient to justify foregoing 0.5 of 1% interest by lending under FILA, particularly since the cost of administering the loans is higher because of increased paper work.

In short, the banks do not have the same need for encouragement (provided by FILA) as they once did to make agricultural loans with terms equitable to other small business loans. Since there is little risk reduction associated with the guarantee, they often prefer to lend under their own programs.

Another factor which has influenced the role of FILA loans has been the expansion of provincial government agricultural lending programs. Between 1960 and 1977, all 10 provinces established, re-organized or expanded their own agricultural credit agencies. Provincial direct intermediate term loans are not significant at the national level. In 1980, direct provincial loans barely accounted for 1% of the intermediate term credit extended to farmers. Provincially guaranteed loans, on the other hand, are significant. At the national level, nearly 6.5% of all intermediate term agricultural credit extended in 1980 was provincially guaranteed. At the local level, these guarantees take on even more importance. In Quebec and Alberta, for example, loans equaling $89 million and $62 million were guaranteed by these provinces, compared with $2 million and $75 million, respectively, guaranteed under FILA.

Farm Credit Corporation statistics indicate that the proportion of its own loans and loans granted by provincial lending agencies for debt consolidation and refinancing have increased dramatically in recent years. Nearly 35% of Farm Credit Act loans were made for this purpose during fiscal 1981, compared with 16% in fiscal 1980. Refinancing and debt consolidation are ineligible under FILA loans. This fact and the shift towards an increasing use of long term debt in agriculture (Farm Credit Corporation) may also help explain the declining importance of FILA.

Finally, the current lending limit of $100 000 per borrower under FILA is perhaps low at a time when a single new implement can cost more than $100 000. This limit may restrict some borrowers from expanding their operations to an economically viable size.

CONCLUSIONS

The introduction of FILA in 1945 was timely. It occurred during a period when large capital investments and, consequently, substantial amounts of credit were required in agriculture but the amount and number of sources of agricultural credit were limited.

The program admirably served its primary clients, farmers and the banks, by providing a guarantee on agricultural loans. Chartered banks, trust companies, credit unions and other lenders now extend significant amounts of agricultural credit. Also, many provinces are guaranteeing substantial amounts of credit to farmers.

As a result of its own success, the importance of FILA has declined in recent years. Fewer loans are being made under the act and its market share has dwindled because rapid increases in the demand for agricultural credit has been met primarily by other lenders.

As FILA approaches its expiration date in 1983, a close examination of its current role in the farm credit field is warranted, particularly in light of current financial conditions in the agricultural sector.

APPENDIX

Revisions to FILA

1947 – Poultry included under livestock purchases

1948 – Claim procedures changed

1952 – Maximum FILA indebtedness increased to $4000

1953 – Maximum aggregate principal outstanding increased to $300 million

1956 – Maximum FILA indebtedness increased to $5000
- Fines for false statements imposed

1959 – Maximum aggregate principal outstanding increased to $400 million
- Maximum FILA indebtedness increased to $7500
- Farming definition expanded to include bees and fur

1962 – Maximum aggregate principal outstanding increased to $500 million

1964 – Maximum FILA indebtedness increased to $15 000

1965 – Maximum aggregate principal outstanding increased to $700 million

1968 – Maximum aggregate principal outstanding increased to $900 million
- Credit unions, trust companies and other lenders introduced
- Loans for additional land accepted with repayment over a maximum of 15 years
- Maximum FILA indebtedness increased to $25 000
- Maximum interest rate chargeable adjusted twice yearly on the basis of yields of selected government bonds

1974 – Maximum aggregate principal outstanding increased to $1100 million
- Maximum FILA indebtedness increased to $50 000
- Alberta Treasury branches introduced as lenders
- Equipment overhauls included under eligible purposes

1977 – Maximum aggregate principal outstanding increased to $1550 million
- Maximum FILA indebtedness increased to $75 000

1978 – Maximum interest rate chargeable allowed to float at bank prime plus 1%

1980 – Maximum FILA indebtedness increased to $100 000

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Notes

OUTLOOK

Agriculture Canada economists predict that food prices for 1982 will average 8-9% above 1981 levels with the largest year-over-year increase toward the end of the year.

The economists also forecast that low prices for wheat and coarse grains will continue because of an expected record wheat crop of 26 million tonnes and large total coarse grain supplies.

Large supplies and low prices are also expected to continue dominating world oilseed markets in 1982-83. In Canada, increased canola plantings in 1982 may not be sufficient to meet an expected large domestic demand.

In the livestock sector, the economists anticipate stronger beef prices for late 1982 and early 1983 as beef production will likely average below year-earlier levels.

Hog prices should continue to be strong as hog marketings are expected to remain low for the next few months.

Bumper crops of most fruits and vegetables in Canada will keep prices down, particularly for potatoes and apples. An August frost has reduced the flue-cured tobacco crop by about 20% and will likely force tobacco prices up by as much as 12% above the minimum guaranteed price.

Canadian farm income in 1982, which had been forecast at about $3.6 billion in July, down 17% from last year's, will likely decline slightly. This is mainly the result of the lower than anticipated prices for grains, oilseeds and special crops.

BRUCELLOSIS ERADICATION

Changes to the Animal Disease and Protection Regulations were recently announced that will support the final thrust to eradicate bovine brucellosis in Canadian cattle by 1987.

Effective October 1, 1982, all cattle dealers are now required to keep records of cattle movements and to ensure that blood tests for brucellosis have been done before accepting certain classes of livestock for sale. In the past, such regulations only applied to dealers operating from their own registered premises.

In addition, several non-regulatory changes have been introduced to support the brucellosis eradication programs, including better diagnostic tests and improved investigative techniques. New blood testing methods are now available and better follow-up and retest procedures have been developed from the knowledge acquired in the last 5 years of the eradication program.

THE JERUSALEM ARTICHOKE

The Jerusalem artichoke is a native North American crop that has come into the limelight recently as a possible source for liquid fuel.

To investigate this potential, Agriculture Canada has awarded a research contract under the Energy Research and Development in Agriculture and Food (ERDAF) Program to Sunroot Energy Ltd. of Orton, Ont.

The ERDAF contract with Sunroot Energy is a wide-ranging research project. It involves variety testing, fertilizer trials and machinery development for harvesting both the tubers and tops of Jerusalem artichoke plants. Special emphasis is being placed on establishing growing techniques and production costs under actual large-scale field conditions.

The results of the large planting of the crop this year will also provide information for Canadian equipment manufacturers to design and construct the specialized equipment necessary for the commercial production of the crop.

Gary Hergert, a mechanization specialist with Agriculture Canada, is scientific authority for the project.

"We know that the yield potential is about 40 t/ha and that with some of the new fermenting techniques being developed, it may be possible to obtain 4000 L of alcohol per hectare," Mr. Hergert says.

"However, production costs could be high. Through the Sunroot Energy contract, we will seek ways to reduce production costs and increase yields to the point where it will make economic sense for the farmer to produce Jerusalem artichoke as an energy crop."

At the same time, Agriculture Canada's Engineering and Statistical Research Institute in Ottawa and the Energy Management and Resource Centre of the Ontario Ministry of Agriculture and Food (OMAF) in Kemptville, Ont., will study production of Jerusalem artichokes in eastern and northern Ontario.

As part of this joint federal-provincial production study, growing trials will be conducted. These will give researchers the opportunity to see Jerusalem artichokes grown under different soil and climatic conditions, including "marginal lands" not suited for most other crops. Also included will be variety, fertilizer and herbicide tests.

In addition, the tests will compare the production rates for both tops and tubers of Jerusalem artichokes to other potential energy crops.

The Jerusalem artichoke could possibly be an energy crop of the future. However, Mr. Hergert advises growers to start with a small test plot to first establish production costs and growing techniques for their local conditions.

He also suggests that farmers interested in liquid fuel production should obtain a copy of Agriculture Canada's "Farm Scale Production and Use of Fuel Alcohol", available from provincial agricultural offices or from Publications, Communications Branch, Agriculture Canada, Ottawa, K1A 0C7.

The federal government, as part of its National Energy Program, is conducting a Farm Energy Survey. The results will help to develop future policies and programs to aid in farm energy security.

Publications

Agricultural Development Planning in Thailand. Iowa State University Press, Ames, Iowa 50010, 1982, 326 pp.

Just published by the Iowa State University Press, this book summarizes significant work done under the Thailand Agricultural Sector Analysis Program. It examines the development and application of agricultural research methods and models in Thailand to allow better agricultural planning, improve the nation's food supply, speed agricultural and economic growth and development, achieve a more equitable distribution of income and improve investment efficiency. The book also shows how to develop an agricultural planning program in an emerging nation with the help of native experts and government officials, and how to train native people to work in and then assume full control of a working system.

Agricultural Development Planning in Thailand is organized as a series of reports on the different phases of the program. Chapter 1 provides background and an overview of the operational philosophy adopted at the outset of the program. Chapter 2 describes the agricultural and rural sectors of Thailand and shows the importance of the agricultural sector in the social and economic systems. Chapter 3 summarizes the activities in the statistics section of this program and gives an overview of the surveys conducted and the data processed.

The next four chapters report on the agricultural production models. They describe the model-building process from the zone models to the national models. Included in these chapters is analysis of the alternative future for the fourth Five-Year Plan and analysis of crop supply potential and employment opportunities in agriculture.

The models being developed to analyze specific commodity programs and policies are discussed in Chapter 8, and Chapter 9 includes a model to evaluate the export situation of Thai rice, emphasizing trade relations among members of the Association of Southeast Asian Nations.

Chapters 10 and 11 of *Agricultural Development Planning in Thailand* review two models developed for macrolevel analysis. Chapter 12 covers the transportation and marketing models developed under the program.

The next four chapters provide short overviews of ongoing model development programs. Covered in these chapters are short-term programs, time-path stimulations for longer-term programs, input-output work and its linkage to the agricultural production models and the most recent program initiated in the sector analysis project. The final two chapters present reflections on the project from the Thai and American program leaders.

Agricultural Development Planning in Thailand is edited by Kenneth J. Nicol, consulting agricultural economist, Alberta, Canada; Somnuk Sriplung, secretary-general, Office of Agricultural Economics, Ministry of Agriculture and Cooperatives, Bangkok, Thailand; and Earl Heady, Charles F. Curtiss Distinguished Professor, professor of economics, and director of the Center for Agricultural and Rural Development, Iowa State University, Ames, Iowa.

Agricultural Marketing Handbook, Third Edition. S.H. Lane, School of Agricultural Economics and Extension Education, University of Guelph, June 1982, 198 pp.

This reference provides a concise and current description of the structure and programs of 24 producer marketing boards, 6 national marketing agencies and 4 federal and provincial regulatory bodies that are involved in the marketing of Ontario agricultural commodities. Information concerning significant changes that have been made in the operation of each of these bodies, as well as a summary statement of the significant features of legislation that is directly relevant to commodity marketing in Ontario and in Canada, is included. *The publication is available for $5.65 plus postage from Campus Cooperative Bookstore, University of Guelph, Guelph, Ontario N1H 6N5.*

Lincomycin Improves Broiler Efficiency. *Available from TUCO Products Company, Marketing Department, Animal Health Division, 40 Centennial Rd., Orangeville, Ontario L9W 3T3.*

This new management report from TUCO Products Company contains the results of recent broiler ration tests conducted in Canada. The tests showed that the antibiotic lincomycin included in broiler rations provides the producer with financial benefits through improved feed efficiency and growth rate of broilers. The report also includes an article from the U.S. on the use of lincomycin plus 3-Nitro compared with Zinc Bacitracin. A breeder management program is discussed, showing how Albamix can be part of the total management program.

Marketing Farm Products: Economic Analysis. Iowa State University Press, Ames, Iowa 50010, 1982, 7th edition, 428 pp. ill.

This seventh edition of the long-established text has been extensively revised to make it relevant to present economic conditions. Major changes have been made in the initial chapter, which outlines the broad problems in agricultural marketing; the chapters on demand for farm products have been substantially revised; a new chapter on formula pricing of farm products has been added with relevant new material; livestock chapters have been completely reorganized, with one concentrating on beef, a second on pork and hog marketing, and both containing substantial new material; and two dairy marketing chapters have been extensively revised and updated. Charts, tables and content in all chapters have been updated.

In contrast to a descriptive discussion of marketing functions, *Marketing Farm Products* uses the analytical approach to marketing farm products. It reviews the general nature of agricultural marketing problems, applies these concepts to general problems of agricultural markets, and considers the particular marketing systems and problems for the major agricultural commodity areas.

This is a problem-solving book, simply and clearly written by two recognized authorities in the field of agricultural marketing. Geoffrey S. Shepherd is professor emeritus of agricultural marketing and price policy. Gene A. Futrell is professor of economics and extension economist. Both are at Iowa State University.

The following six publications are available without charge from the Distribution Center, Room B-151, Sir John Carling Building, Agriculture Canada, Ottawa K1A 0C5.

Agricultural Trade Facts, 1981. 10 pp.

Canada's Trade in Agricultural Products 1979, 1980 and 1981. G. LaBrosse and E. McSorley. Publication No. 82/3, September 1982, 85 pp.

The Impact of Rising Food Prices on Low-Income Consumers. Don G. Roberts, September 1982, 29 pp.

Incomes of Farm Taxfilers, 1978. J. Lablanc-Cooke, D. Karamchandani and W. Darcovich, June 1982, 182 pp.

Market Commentary, September 1982. 53 pp.

Selected Agricultural Statistics for Canada and the Provinces 1982. May 1982, 101 pp.

The following 3 publications are available through bookstores or from the United Nations, Sales Section, New York or Geneva.

Agricultural Trade in Europe, Recent Developments (prepared in 1981). Economic Commission for Europe, Agricultural Trade Review No. 19, Sales No. E.82.11. E.11, New York, 1982.

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NOTICE

Please note that Numbers 1, 2, 5 and 6 of CFE for 1982 were not published.

FOREWORD

In the spring of 1980, Mr. Wayne Ormrod, Director of Pesticides Division at Agriculture Canada, asked researchers in the Research Branch to undertake, in cooperation with the then Policy Planning and Economics Branch, research related to pesticides. The objective was to assess the feasibility of applying the principles of risk-benefit analysis to regulation of the use of pesticides. Mr. Ormrod asked the researchers to apply their agricultural expertise to study the economic benefits of the extensively used herbicide 2,4-D.

In this special edition, the initial results of this research effort are reported. The first of three articles provides a general discussion of risk-benefit analysis and how, in principle, this technique may be useful for regulating pesticides. The second reports the researchers' findings on the economic benefits of 2,4-D, and the third on the fungicide, captan. It should be noted that in both of these empirical articles, information is given on *benefits only.*

The department has begun the second phase of this research program in cooperation with Health and Welfare Canada, Environment Canada, and Fisheries and Oceans Canada. The objective in this case is to assess the feasibility of performing complete, integrated risk-benefit analyses pertaining to chemicals.

NOTICE

The articles in this issue report research involving pesticides. None of the articles contain any recommendation for use of chemicals; nor is it implied that the various uses discussed here have been registered. Use of company and product names is for identification only and does not imply endorsement. The formal risk-benefit technique discussed in these articles is still at the experimental stage and is not currently used for registering pesticides in Canada.

The views expressed in this issue are the authors' and not necessarily those of Agriculture Canada.

Regulation of pesticides and risk-benefit analysis: Can it help?

Ed Dunnett

ACKNOWLEDGEMENTS

The author gratefully acknowledges valuable comments received on an earlier draft from Mr. Mik Bickis of Health and Welfare Canada. These comments dealt, in the main, with the section on risk analysis. Valuable comments were also received from Mr. Malcolm Stewart of Pesticides Division, and Mr. Ron Krystynak of the Food Regulation Analysis Section, both of Agriculture Canada. Responsibility for the use of these comments remains with the author.

INTRODUCTION

The purpose of this article is to describe risk-benefit analysis briefly and to indicate how the analysis may be useful to the process of establishing pesticide regulations.[1]

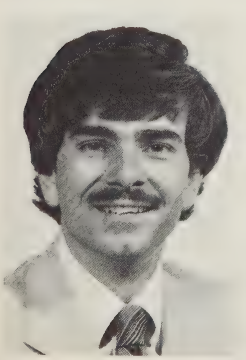
In Canada, governments closely control pesticide sales and use. Before any new pest control chemical can be sold, its manufacturer must submit detailed data to government officials demonstrating that the material is not only effective for pest control but also that it is safe to the general population and to the environment, when used as directed. This pre-sale assessment is particularly effective in establishing the safety, merit, and value of new products as they are being developed and introduced. A problem can arise, however, if new discoveries or new information about safety emerges during the re-evaluation of older materials after they have been on the market for some time.[2] How should these new data be interpreted? On the one hand, there is a responsibility to ensure public safety. On the other hand, there are often concerns about the social and economic consequences and disruptions entailed in suddenly removing a product from the market.

In such a situation, risk-benefit analysis may play an important role. Basically, risk-benefit analysis is a means of organizing and analyzing data to provide answers to the following types of questions. How many Canadians are currently exposed to the chemical and in what way? How much of the chemical under investigation are Canadians currently exposed to?

How many people, if any, may be expected to develop health problems as a consequence of being exposed to the chemical? What would the economic losses be from regulatory action aimed at reducing exposure? What method of reducing exposure to acceptable levels is least costly to the economy? In short, risk-benefit analysis is a means of measuring or attempting to measure specific effects. It can be useful in helping to resolve certain controversies regarding safety and economics.

The goal of the analysis is to derive specific measures of both the risks and the benefits from using a specific chemical. However, to both the decision maker and the reader, a word of caution is in order against expecting too much from the analysis and its results. As explained in a recent study on food additives,[3] the problem is that analytical methods have not yet been developed to the point where experts can entirely agree on the reliability and completeness of the results. This is true of both the risk and benefit assessments. In view of the limitations that must be attached to the results, some may argue against even attempting an analysis. In defence of risk-benefit analysis, it must be pointed out that it may reduce, if not eliminate, the uncertainty about the effects of regulatory action against the use of a chemical. And risk-benefit analysis is useful in that it assembles the known and available facts required for a decision. The scientist attempting a risk-benefit analysis must take great care in explaining the *limitations* of any results obtained as well as the results themselves. Provided these limitations are communicated and appreciated, risk-benefit may be

[1]For additional information on pesticide regulation and related issues, see Agriculture Canada's Publication No. 1518, *Pesticides: Their Implications for Agriculture* or the leaflet, *Let's Talk About Pesticides*, available in most agricultural libraries across Canada and from Communications Branch, Agriculture Canada, Ottawa, Ontario, K1A 0C7.



Mr. E.S. Dunnett is Chief, Food Regulation Analysis Section, Food Markets Analysis Division.

[2]A review of older chemicals is a routine part of the regulatory process.

[3]United States General Accounting Office Report to the Congress of the United States, *Regulation of Cancer Causing Food Additives - Time for Change?* December 1981

a useful guide in making and explaining a decision in a very difficult situation.

RISK ANALYSIS

In analyzing any toxic or potentially toxic substance including pesticides, scientists conducting a risk analysis attempt to establish a relationship between numbers of people suffering adverse health problems among a given population and dose of the chemical that it is exposed to. Such a relationship, it should be noted, actually contains two ideas. The first is that only a fraction of the population may be expected to succumb to a particular dose level of a chemical. And the second is that the percentage of people adversely affected may be expected to rise as the population is exposed to higher doses.

There are two fundamentally different explanations for this relationship, either of which could hold for a particular chemical. The first explanation is based on different individuals having differing abilities to tolerate a specific dose of a substance, so that some will be affected while others will not. Furthermore, the ability to tolerate a substance breaks down as the individual is exposed to higher and higher doses. The second explanation also contains two ideas. Certain toxicological responses (for example, cancer) are the result of a combination of independent events, so that exposure to a chemical merely modifies the chances of an individual responding adversely. The chances of responding are increased with increasing doses.

Mere knowledge of the risk relationship does not permit the scientist to say which individuals are affected by a particular chemical. But based on analyses of sample data and a knowledge of doses the population is exposed to, we should be able to describe risks for the population as a whole.

There are numerous technical and statistical difficulties in computing the risk relationship described above. For example, what do we mean by dose — a single exposure or repeated exposures over time? A second serious difficulty is obtaining sufficient data on groups exposed to different levels. Such data are obviously vital for identifying the response rate to increasing doses. And a third major difficulty is identifying the toxicological response in cases where a large gap in time separates the development of disease symptoms and initial exposure.

Because of these and other difficulties, scientists often turn to test animals for experiments. Identical populations can be divided into groups and exposed to different levels of the chemical, and the results can be observed directly. But here another serious difficulty emerges.

As we are typically interested in establishing very low risks for safety purposes, very large numbers of test animals would be required if we were to try to observe safe doses or virtually safe doses directly. Moreover, for statistical reasons there is a danger of failing to detect a carcinogen by comparing the number of tumors in test animals exposed to low doses of the chemical to the number in a group not exposed to it. The solution is to increase the dose significantly above the low level and to make observations about risk at the high levels. Once the relationship is established at high dosage levels, the scientist attempts to extrapolate the relationship back outside the observed range to much lower doses and describes the risks at these exposure levels — an unreliable procedure. Yet another difficulty with this approach is inferring risks about *human* populations from test results obtained in *animal* studies.

The success of a risk analysis depends directly on the degree to which these and other statistical difficulties can be overcome. In view of the difficulties, the reader will not be surprised to learn that in some cases, considerable uncertainty will remain about whether a substance is carcinogenic in humans and about its potency even after a risk analysis has been completed. At this point, a key issue becomes how much proof of carcinogenicity is required to warrant taking action against a substance.

In addition to undertaking an analysis of health risks, the analyst must consider environmental risks. Does use of a particular chemical lead to any vegetation damage, animal losses, losses of recreational areas, or other adverse environmental effects? A key factor to be examined in an environmental risk study is the extent to which the chemical moves and persists in the environment.

BENEFIT ANALYSIS

In contrast to a risk analysis, a benefit analysis attempts to measure the socio-economic benefits that accrue to users of a technique and to society at large. In broad terms, a pesticide provides benefits by increasing agricultural productivity, that is to say, increasing outputs from a given volume of inputs. For example, a herbicide boosts grain production from a given volume of farm inputs by reducing competition from weeds. As developed in Rovinsky and Reichelderfer, the size of these benefits, measured in dollars, depends directly upon the destructive potential of the pest, the extent to which the pesticide is used, and the quality and cost of alternative means of controlling the pest. A pesticide, widely used against a highly destructive pest, with no close substitutes clearly contributes a great deal to agricultural productivity. The benefits would be lost if use of the chemical were to be prohibited for safety reasons.

Benefits are widely disseminated. Agricultural pesticides raise farm operators' production capability and net income. Other groups stand to gain as well. Chemical companies certainly can be expected to earn benefits from manufacturing and sales. And consumers of food treated with the chemical during production normally gain from lower cost and higher quality. In the case of chemicals used in the production of grain in Canada, for example, these consumer benefits may accrue not only to Canadian but to foreign consumers — in some cases, residents of very poor countries helped out by food aid programs. In short, benefits are often widely dispersed and important to a number of groups beyond those involved in the purchase and sale of chemicals.

While there are no major difficulties in the concept of a benefit study, in practice it is often a challenge to compute a specific dollar value for a specific pesticide compound. On one hand, a great deal of data must be obtained on the use of the compound, as well as its effectiveness in increasing product yield compared with that of the next best alternative or alternatives. Moreover, some projection must be made about how growers would react if a certain material were no longer available: would they spray with an alternative, would they change their crop, how would they respond? In approaching this problem, a researcher may rely on the judgement of informed experts to predict a response or use a sophisticated econometric or linear programming model where relevant and available. And finally, a benefit study must consider future as well as present benefits. As the level of benefits depends on the quality of alternatives, it is necessary to consider what new substitutes might be introduced, what alternatives might lose their effectiveness because of pest resistance and what alternatives might subsequently be removed from the market for health and safety reasons.

In short, there are a number of technical difficulties in benefit analysis as there are in risk analysis. In some cases, it may not be possible to do an analysis at all, in others, only a partial or incomplete analysis may be possible.

COST-EFFECTIVENESS ANALYSIS

The benefit analysis of a chemical provides useful information on the economic effects of curtailing all its uses. In some cases, additional information may be required to aid in the decision-making process. For example, if it is determined through toxicological tests that exposure of the population to a chemical must be reduced for safety reasons to a certain level, a decision must be made on the most efficient course of action. In a cost effectiveness study, the researcher considers all the possible means of reducing exposure and determines the method which is least costly or least damaging to the economy. For example, if it were possible to reduce exposure of the population to a chemical simply by encouraging people to use it with more care, persuasion would clearly be far less costly than removing the chemical from the market. The objective is to review the range of alternatives that would reduce exposure and to determine the most cost-effective approach.

As explained in more detail in van Ravenswaay, exposure to a certain chemical may be reduced through various regulatory strategies. The obvious way is to place limitations, including bans, either on permitted uses of the chemical or on marketing of products containing its residues. But other options should be explored as well. Some of these, such as protective suits for pesticide applicators and safety instructions for uses, involve additional expenditures. Others involve modifying the form in which the chemical products are to be available, for example, pellets rather than powder. The cost-effectiveness analysts should consider all of these, subject to the options being practical, legal (i.e., statutory authority for such options exists), and, most importantly, enforceable.

CONCLUSION

The summary of the application of risk analysis, benefit analysis, and cost effectiveness analysis to regulation of the use of pesticides and the brief overview of the possible methods and limitations (often severe ones) of the results raises the key question: how useful are the results of this work likely to be?

While the method is new and largely untested, it is possible to suggest three advantages to the risk-benefit approach. First, risk-benefit can be useful for providing information about the likely effect of different regulatory options for dealing with a toxic chemical problem. For example, in considering the impact of prohibiting the use of a particular chemical, a risk assessment would include a statement not only about reduced risks from reduced exposure to the chemical, but also about any increased risk from additional use of alternatives in its place. While often limited by uncertainty and gaps in data and knowledge, this information may be used by decision making bodies or groups, along with any other input deemed pertinent, to make specific regulatory decisions. In other words, risk-benefit analysis can assist in the decision-making or solution-finding processes. A second advantage or potential advantage derives from the fact that a risk-benefit study of a particular toxic chemical contains or should contain a detailed discussion of the problem at hand and a comparison of alternative solutions. It assembles the important relevant facts and analyzes these facts to the limits of current knowledge. Such a document, or, more likely, the summary of such a document can provide a rationale to the public for action or inaction on a problem. A third potential advantage is that a risk-benefit study can highlight gaps in data or knowledge that limit information on which to base a particular decision. The study can identify

what would be required to help fill these gaps for similar studies and what benefits would be derived from these efforts. It may, for example, suggest different types of surveys or changes in research priorities as a means of improving sources of information upon which to base specific regulatory decisions in the future.

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An economic assessment of 2,4-D in Canada: The case of grain

Ronald Krystynak

ACKNOWLEDGEMENTS

The author would like to express his appreciation to the contributors of data to this report including members of the Expert Committee on Weeds, Dr. A.G. Thomas, Regina Research Station, Mr. M. Daciw of the Manitoba Department of Agriculture, and the Chemicals Branch, Department of Industry, Trade and Commerce. I would also like to acknowledge the helpful comments made on earlier drafts of this report by Mr. E. Dunnett and by the members of the 2,4-D Study Steering Committee which included Mr. B.H. Davey, Dr. W. Saidak, Mr. I. Furniss, Mr. M. Stewart, and Mr. V. Heighton. Full responsibility for the use of the data and contents of the report, of course, remains with the author.

2,4-D is an important herbicide for the control of broadleaved weeds, especially in grain production. For the year 1979 some 3900 t of 2,4-D (acid equivalent) were applied on approximately 7.9 Mha of wheat, barley, and oats in western Canada, about one-half the area planted to these crops. Relatively smaller amounts of 2,4-D were also applied to cereal and corn crops in eastern Canada. Other uses of 2,4-D, such as brush control and home and garden use, accounted for additional 2,4-D usage.

It was estimated from 1979 values that yield increases from using 2,4-D contributed approximately $214 million to the gross value of small grain production in Canada and perhaps an additional $4 million because of the quality of the grain. This represents about 7.4% of the total value of farm receipts for wheat, barley, and oats for 1979. The net increase in grain value, once herbicide and application costs were deducted, was $176 million.

If 2,4-D use were prohibited for grain production, the additional cost due to yield losses and use of more expensive, less effective herbicides would be at least $66 million and perhaps much higher. Other factors that may be affected by a curtailment of 2,4-D use, such as grain quality, dockage, farm energy use, and farm income, were also examined by this study.

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INTRODUCTION

Weeds have posed a problem to agriculture since about 10 000 B.C. when humans started to cultivate crops. Weeds were undoubtedly recognized as undesirable from the beginning as competition from the weeds reduced the yield of the seeded crops. At first they would have been removed by hand. [1] At about 6000 B.C., primitive hand tools were used to till the land and destroy weeds. As early as 1000 B.C. oxen were used to pull harrows and it was during this period that crops first were planted in rows so that animals would not walk on the plants. Mechanization did not affect agriculture substantially until the beginning of the twentieth century when gasoline tractors were introduced, to be followed by many new mechanical weed control implements.

In Canada interest in chemicals to control weeds began in the 1920s. During the 1930s and early 1940s there was limited use of sodium chlorate, sodium arsenite, sulfuric acid and dinitrophenols. [2] However, it was not until the success of 2,4-D, which was introduced commercially in 1946, that the present era of herbicides was launched. 2,4-D is a selective herbicide that gives excellent control of wild mustard, lamb's quarters, and many other broadleaved weeds in grain crops. Unfortunately, it can not be used in all crops and it does not control important weeds such as wild oats, wild buckwheat, and green foxtail. Research on herbicides has continued and by 1980, 131 different herbicides were registered for sale in Canada. Now most weeds in grain crops, oilseed crops, vegetable crops, tree fruits, small fruits, and nursery stock can be sucessfully controlled with chemicals.

In Canada, the sale and use of herbicides, as well as other pesticides, are regulated under the authority of the Pest Control Products Act administered by Agriculture Canada. The intent of the Act is to ensure that the use of a pest control product is effective

[1] Hay, J.R., "Gains to the Grower from Weed Science," *Weed Science*, 1974, 22(5): 439-442

[2] National Executive Expert Committee on Weeds, A Statement of the Expert Committe on Weeds – Position on Herbicide Use, 1980, p. 6

and safe for the recommended usage and does not impose undue hazards to human health or the environment. The Act requires that all pest control products be registered before their sale and use, and the registration accompanied by supporting efficacy and safety data. The staff of Agriculture Canada evaluate these data in consultation with experts from other interested federal departments including Environment, Fisheries and Oceans, and Health and Welfare. Further restrictions on the use of herbicides may be imposed through provincial pesticide legislation and municipal by-laws.

Concern over environmental hazards has led to the cancellation of a number of important pesticides in Canada (e.g., DDT). In any decision-making process to consider the prohibition or limitation of the use of a specific pesticide, it is important that the economic benefits of the pesticides be weighed against the environmental risk.

In this paper I will indicate how the benefits of 2,4-D use may be calculated and derive specific estimates for Canada. In other words, I will attempt to document the importance of 2,4-D use to the production of grain in Canada. Specifically, I will examine the major use of the herbicide, in small grain production (wheat, barley, and oats). I will not try to quantify the minor uses of the herbicide, largely because of the limited data available in those areas.

It can be shown that the economic benefits of any particular pesticide will depend largely on the extent to which the pesticide is used, the cost and efficacy of the affected pesticide, and the cost and efficacy of alternative pest control materials or techniques. [3] The benefits of a particular pesticide to the economy and to its individual users are greater in cases where the pesticide is used extensively and where there is no actual or potential substitute for it. The benefits may also be viewed by considering the economic consequences of a pesticide prohibition. These consequences are potentially measurable, particularly if the pesticide is used in a commercial farming operation. They are increased production costs from using substitute pest control materials and a reduced value of output produced where substitute pest control techniques result in a lower yield or a crop of lower quality. In addition to these direct economic costs, there are other important economic issues to be considered. A prohibition order may affect the supplier. Other concerns include possible effects on output prices, potential changes in energy consumption, and in some cases, effects on the international balance of payments.

Very little published research is available on the economic impact in Canada of a selected pesticide. [4] In the U.S., biologic and economic assessments of various pesticides have been performed (although not on 2,4-D) as part of the Rebuttable Presumption Against Registration (RPAR) Process.

USES OF 2,4-D IN CANADA

2,4-D in its various formulations is a selective herbicide employed for the control of broadleaved weeds. It is a "translocated" type of herbicide, meaning that it must be absorbed by leaf cells in order to be effective. Hence it is toxic to many broadleaved plants but is relatively non-toxic to crops of the grass family.

It is used mainly in grain crops (wheat, barley, oats, rye, and corn) to control broadleaved weeds such as wild mustard and lamb's quarters. It is usually applied after the crop has emerged (i.e., post-emergent). 2,4-D can also be used either separately or in combination with other herbicides to control the growth of brush or woody plants in various circumstances. In forestry management programs it helps conifers to reestablish themselves by keeping down competition from poplar and other fast-growing trees of lower economic value. 2,4-D use is also important for brush control in that it maintains rights of way, especially for hydro power transmission lines. It also helps keep roadsides clear for better visibility, control of noxious weeds, and easier snow removal. 2,4-D is also used to keep residential lawns and public parks free of weeds such as dandelions.

No comprehensive published statistics on current 2,4-D usage in Canada are available. For the years 1947 to 1977 Statistics Canada collected and published annual figures on sales of 2,4-D, as well as other pesticides. For the most recent years, these data were broken down for agricultural, industrial, and home use. The Manitoba Department of Agriculture has collected data on herbicide use in the four western provinces from 1947 to the present. However, there are some discrepancies between the Manitoba Department of Agriculture data and the Statistics Canada data, the reasons for which could not be determined. Data on current use were obtained from various published and unpublished sources.

The Historical Use of 2,4-D in Canada

The discovery of 2,4-D was first reported in 1941 in the United States. [5] This chemical, a synthetic plant hormone, was first recognized as a growth regulator.

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[3] For elaboration of these ideas see Rovinsky, Robert B. and K.H. Reichelderfer, Interregional Impacts of a Pesticide Ban under Alternate Farm Programs, United States Department of Agriculture, p. 1.

[4] F.A. Holm and J. McKell have authored a brief study, The Economic Impact of 2,4-D on the Saskatchewan Wheat Crop, mimeo, 1981.

[5] Peterson, Gale E., "The Discovery and Development of 2,4-D," Agricultural History, 41 (1967): 243-253

Its potential as a herbicide was recognized in 1944 and testing of the product for agricultural use started in the U.S. and Canada in 1945. Commercial use on farms began in Canada in 1947. Statistics Canada data indicate that sales of all formulations of 2,4-D that year amounted to 346 t [6] at a value of $544 thousand dollars.

Tables 1 and 2 present Statistics Canada data on historical sales of 2,4-D and other herbicides for agricultural purposes during selected years between 1948 and 1977. Tables 3 and 4 present historical data obtained from the Manitoba Department of Agriculture on quantities of 2,4-D and other herbicides sold and an estimate of the area to which they were applied, for the four western provinces. Sales in the four western provinces would represent the bulk of sales of 2,4-D and MCPA (another phenoxy herbicide similar to 2,4-D).

Some discrepancies were observed between the Statistics Canada data and the Manitoba Department of Agriculture data. For instance, for the years 1976 and 1977, sales of 2,4-D in the four western provinces (Manitoba Department of Agriculture data) are shown to be larger than for all of Canada (Statistics Canada data). Also, for 1969, Statistics Canada data for Canada show an increase of 2,4-D sold to 7200 t from 5700 t in 1968, while Manitoba Department of Agriculture data for the four western provinces show a decline in 1969 to 2700 t from 4200 t in 1968.

The reason for the discrepancies is not known but some of the evidence suggests that the Manitoba Department of Agriculture data are the more accurate. For example, 1969 area sown to grain in the prairie provinces declined, prices for grain fell, and grain stocks on farms increased. On this evidence, one would expect 2,4-D and other herbicide use to decline (as shown by the Manitoba Department of Agriculture data) rather than increase (as per Statistics Canada data).

Despite the doubts about the accuracy of the data, some general observations can be made as to the trend in 2,4-D use. Since its introduction in 1947, 2,4-D sales quickly rose to about 1700 t in 1950 (Statistics Canada data). Sales rose more gradually after that and peaked in 1968 (Manitoba data) at about 5000 to 6000 t. A period of slow grain sales saw 2,4-D usage drop during the 1969-70 period, begin to recover after 1971, and continue to increase up to the present, yet never surpass the 1968 high (Manitoba data).

[6] Weight of 2,4-D is measured in terms of acid equivalent.

During the same period, MCPA formulation sales increased steadily from yearly averages during 1958-60 of less than 300 t to current ones estimated to be approximately 2000 t (Manitoba data). With the steady growth in the sales of MCPA, sales of 2,4-D as a percentage of total phenoxy sales steadily declined during the 1960s and 1970s. 2,4-D still made up about 65% of total phenoxy sales in quantity (Statistics Canada and Manitoba data) and over 50% of total value (Statistics Canada) for the 1975-77 period.

The introduction of many new herbicides has resulted in a reduction of the proportion of 2,4-D as a percentage of total sales of agricultural herbicides. 2,4-D made up over 64% of total agricultural herbicide sales during 1967-69, decreasing to 16% of total agricultural herbicide sales during 1975-77 (Statistics Canada). This coincided with a marked increase in total agricultural herbicide sales from just over a 9000 t yearly average during 1967-69 to roughly 17 700 t yearly during 1975-77. In terms of value, the increase was from $27 million yearly during 1967-69 to over $135 million yearly during 1975-77 (Statistics Canada data). Data obtained from the Canadian Agricultural Chemicals Association (CACA) for 1978-80 indicate that the sales value for herbicides continues to increase. It was $228 million in 1978, $297 million in 1979, and $321 million in 1980. [7] The marked increase in recent years can be attributed to greater variety and use of such specialty herbicides as wild oat chemicals in the prairie provinces and atrazine in eastern Canadian corn. Over 130 different herbicides are now registered for sale in Canada.

Current Uses of 2,4-D

While comprehensive published data on the quantity of 2,4-D used for various purposes are not available, data assembled from various sources provide a good estimate of how and where 2,4-D is used.

The bulk of 2,4-D is applied to cereal crops in western Canada. Data from the Manitoba Department of Agriculture indicate that in 1979 approximately 3900 t of 2,4-D were applied to cereals in western Canada. [8] The extent of usage, by province, is presented in Table 5, for the periods 1976-78 and 1979. Based on the 4-year average 1976-79, 2,4-D agricultural use in Saskatchewan represents 55.2% of the total of the four western provinces while Manitoba used 25.1%, Alberta 19.4%, and British

[7] CACA figures represent retail dollar sales value while respondents to the Statistics Canada survey were asked to report the value of each product on the basis of final sales value received. Thus figures from the two sources are not strictly comparable.

[8] The year 1979 was chosen because it represents a typical year, is fairly recent, and sufficient data are available for it.

TABLE 1. SALES OF HERBICIDES BY CANADIAN REGISTRANTS

	1948[1]	1949	1950	1958	1959	1960	1967	1968	1969	1975	1976	1977
	tonnes											
Agricultural herbicides												
2,4-D formulations[2]												
Amine	119.7	301.3	363.3	301.8	303.2	409.8	964.4	1 106.8	1 759.3	1 234.8	1 179.5	1 1404.0
Ester	772.9	323.0	1 278.6	1 276.5	1 637.3	2 287.3	3 455.9	4 393.7	4 339.8	2 177.0	1 202.0	1 008.0
Other[4]	100.7	117.8	87.9	101.9	101.1	81.3	219.9	158.2	1 135.7	140.9	x[3]	174.3
Total 2,4-D	993.3	742.1	1 729.8	1 680.1	2 041.5	2 778.4	4 640.1	5 658.7	7 234.9	3 552.7	2 381.5	2 586.2
MCPA formulations	–	–	–	281.0	229.2	350.6	1 188.0	1 235.2	1 202.8	1 203.5	1 203.0	1 110.8
Other phenoxy herbicides[5]	–	–	–	262.2	264.1	135.4	209.9	320.6	245.8	499.9	508.3	624.9
Total phenoxy herbicides	993.3	742.1	1 729.8	2 223.3	2 534.8	3 264.4	6 038.0	7 214.5	8 683.5	5 256.1	4 428.8	4 321.9
Total agricultural herbicides[6]	–	–	–	4 498.6	6 047.3	5 467.7	8 069.9	9 021.6	10 196.6	21 617.8	15 275.1	16 124.9

[1] Annual figures are for the period ending September 30, not calendar years.

[2] Firms reporting 2,4-D were asked to record their sales on the basis of acid equivalent.

[3] x: Restricted Data.

[4] Other 2,4-D: 2,4-D portion of 2,4-D and 2,4,5-T mixtures is listed under other 2,4-D.

[5] Other Phenoxy Herbicides: (Includes 2,4,5-T formulations, 2,4,5-T portion of 2,4-D and 2,4,5-T mixtures, 2,4-DB; MCPB; MCPB+MCPA; CMPP; CMPP+2, 4-D; 2,4,5-TP; 2,4-DP; 2,4-DP+2, 4-D)

The portion of 2,4-D in other phenoxy and non-phenoxy herbicide mixtures is not included in the Total 2,4-D figures and therefore underscores the usage of this product.

[6] Total Agriculture Herbicides can include the phenoxy herbicides TCA and its formulations, carbamate herbicides, sustituted near herbicides, Triazines Dinitros, other pre-emergent herbicides, and non-selective post-emergent herbicides.

Source: Statistics Canada, *Sales of Pest Control Products by Canadian Registrants*, Cat. No. 46-212.

TABLE 2. SALES OF HERBICIDES BY CANADIAN REGISTRANTS

	1948	1949	1950	1958	1959	1960	1967	1968	1969	1975	1976	1977
	$'000											
Agricultural herbicides												
Amine	409.2	690.0	697.6	495.8	587.7	796.7	1 287.1	1 533.9	1 763.2	4 050.1	3 670.4	3 853.8
Ester	1 937.3	1 802.9	3 619.9	2 152.3	2 989.5	3 951.5	4 538.2	4 626.1	5 060.2	7 121.0	4 027.8	3 174.7
Other	149.9	69.8	367.7	18.8	128.7	99.4	515.6	375.6	1 406.4	426.3	x[1]	812.5
Total 2,4-D	2 496.4	2 562.7	4 685.2	2 666.9	3 705.9	4 847.6	6 340.9	6 535.6	8 229.8	11 597.4	7 698.2	7 841.0
MCPA formulations	–	–	–	717.5	670.8	1 007.8	2 685.5	2 705.1	2 622.4	6 186.8	5 655.9	4 921.0
Other phenoxy herbicides	–	–	–	976.3	984.4	682.5	539.4	420.9	594.8	3 429.0	3 687.5	2 258.7
Total phenoxy herbicides	2 496.4	2 562.7	4 685.2	4 360.7	5 361.1	6 537.9	9 565.8	9 661.6	11 447.1	21 984.9	17 760.3	15 020.7
Total agricultural herbicides	3 569.5	4 676.4	5 762.7	5 666.0	7 608.1	8 396.2	19 672.2	34 671.6	27 524.1	127 147.7	153 670.6	125 159.4

[1] Restricted data

Source: Statistics Canada, Sales of Pest Control Products by Canadian Registrants, Cat. No. 46-212.

Columbia 0.3%. The data also provide information on the 2,4-D formulations used in western Canada. For 1979, approximately 40% of 2,4-D used was the amine formulation, the remainder being the ester.

The Manitoba data also indicate the importance of MCPA, another phenoxy herbicide, to western Canadian agriculture. Some 2000 t of MCPA were applied to western cereals. Of the phenoxy herbicide sales for the period 1976-79, MCPA represented 33.8% of the total and 2,4-D 66.2%.

Of the 15.4 Mha of wheat, barley, oats, and rye planted in western Canada in 1979, about 7.9 Mha (51%) were treated either with 2,4-D by itself or 2,4-D mixed with another herbicide. [9] Furthermore, MCPA treated area for 1979 was approximately 4.3 Mha, [10] which is about 26% of all the wheat, barley, oat, rye, and flaxseed acreage in western Canada. Altogether approximately 77% of the area planted to cereals in western Canada in 1979 was treated with 2,4-D and MCPA.

Data on Ontario usage of 2,4-D are available only for the year 1978 and are presented in Table 6. The data indicate that in that year approximately 169 t of 2,4-D (alone or in mixtures) was applied on 311 000 ha of crop in Ontario. The bulk of the 2,4-D, or approximately 135 t, was used on grain. MCPA use in Ontario was estimated to be 97 t. By way of comparison, 2,4-D use in crops in Ontario in 1978 represented only 4.2% of that used in the four western provinces for that year.

Data on the agricultural use of 2,4-D in Quebec and the Maritime provinces were not available but based on available information the quantities of 2,4-D used for agricultural purposes in these provinces are estimated to be very small.

Some data are also available on 2,4-D use for other purposes. Estimates for the 1980-81 period indicate that between 160 and 320 t of 2,4-D are used for forestry and brush control in Canada (Table 7). Data for 1977 indicate that 82 t of herbicide products containing 2,4-D were sold for home and garden use. Of this figure perhaps one-third, or 22 t, would be attributable to 2,4-D. Data on use of 2,4-D in vegetable and forage production and by municipalities were not estimated but are believed to be small relative to the estimated total. In summary, approximately 85 to 90% of the 2,4-D sold in Canada is used in the prairie provinces in the production of cereal crops.

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[9] Area calculation based on using recommended application rates of 0.56 kg/ha for 2,4-D alone and 0.42 kg/ha for 2,4-D in mixtures.

[10] Using same application rates as for 2,4-D.

TABLE 3. HERBICIDES USED AGRICULTURALLY IN WESTERN CANADA FOR WEED CONTROL

Year	2,4-D	MCPA	Others[1]
		tonnes	
1959	2084	256	
1960	2543	410	
1961	2376	389	
1962	3579	504	
1963	3328	575	94
1964	3189	585	156
1965	3504	696	296
1966	3636	856	376
1967	3442	1051	434
1968	4245	1208	590
1969	2679	1121	482
1970	1923	1035	420
1971	2444	1261	623
1972	3623	1405	559
1973	3275	1615	623
1974	3973	1676	998
1975	2864	1378	926
1976	2866	1473	943
1977	3506	1925	1098
1978	3994	1924	1476
1979	3915	1956	1829
1980	2916	1877	1548
1981	3581	2028	2252
1982	3158	1917	3133

[1] Includes TCA, Dalapon, Dicamba, Bromoxynil, Dichloroprop, Niclofen, Stampede, Roundup, and others.

Source: M. Daciw, Agriculture Economics Branch, Manitoba Department of Agriculture

IMPACT OF 2,4-D NON-AVAILABILITY

Methodology

A number of methodological approaches have been used to estimate the costs in the case where use of a specific pesticide is not permitted. One of the first methods employed was the partial budgeting approach. This approach has been used in the Rebuttable Presumption Against Registration studies conducted in the United States including "The Biologic and Economic Assessment of 2,4,5-T." [11] Other, more sophisticated, approaches based on linear programming and econometric models have also been used in studies conducted in the United States. The advantage of models is that they are capable of predicting the behavioral response to a regulatory action, such as restricting use of a specific pesticide. The nature of the response may significantly affect the outcome of the regulatory action.

For this study, the partial budgeting approach has been selected. It has the advantage of being a simple approach that clearly indicates how the results are obtained. It also represents a useful way of collecting, organizing, and analyzing the data. Although linear programming and econometric models have greater predictive capability, they were not used for this study because they require additional and better data, and entail higher costs and a longer time frame. In fact, the inadequate quality of the cost and, especially, the yield data raise doubts about the appropriateness of using sophisticated models, the results of which may lend an unwarranted aura of credibility to the estimates generated.

A budget is essentially a written plan of resource allocation that includes the anticipated physical and financial outcome of that plan. [12] In the case of a pesticide cancellation, budgeting involves the evaluation of expected inputs, outputs, costs, and revenues resulting from the absence of the pesticide. In any budgetary analysis, data of both a technical and financial nature are required. Among the technical

[11] A Report of the United States Department of Agriculture - States - Environmental Protection Agency (EPA) 2,4,5-T Rebuttable Presumption Against Registration (RPAR) Assessment Team, 1979, The Biologic and Economic Assessment of 2,4,5-T.

[12] Rae, A.N., Crop Management Economics, (New York: St. Martin's Press), 1977

TABLE 4. AREA OF HERBICIDE USAGE IN WESTERN CANADA

Year	2,4-D	MCPA	Wild Oat Chemicals
		kha	
1947	202[1]		
1948	1787[1]		
1949	3318[1]		
1950	5490[1]		
1951	4583[1]		
1952	5462[1]		
1953	4905[1]		
1954	4524[1]		
1955	5552	115	
1956	5912	703	
1957	5435	828	
1958	4500	654	
1959	5827	628	
1960	7893	1047	
1961	6680	919	
1962	9591	1170	
1963	9008	1343	
1964	7947	1279	
1965	9251	1472	
1966	9221	1740	344
1967	8566	2049	528
1968	10063	2371	647
1969	6049	2199	556
1970	4522	1942	364
1971	5153	2333	579
1972	8645	2645	744
1973	7570	3012	1652
1974	8452	3027	2770
1975	6006	2477	3737
1976	5945	2630	4310
1977	7203	3428	5350
1978			6942
1979			8043

[1] Include MCPA-treated area

Source: M. Daciw, Agriculture Economics Branch, Manitoba Department of Agriculture

data that are needed is the specification of quantity of inputs and outputs involved, and the financial data required include output prices and factor costs.

For this study, technical data were obtained by polling weed scientists and agricultural experts across the country, and by referring to published data, in order to determine how 2,4-D was being used, how effective 2,4-D is in increasing crop yield and crop quality, and what alternative weed control methods are available, what they would cost, how they would be used, and how effective they would be relative to 2,4-D in maintaining crop yield and crop quality. In examining the effects of a pesticide cancellation, the results are particularly sensitive to the yield values used. Consequently, this study relies on not only expert opinion but also experimental evidence and other approaches to establish the magnitude of the yield effects. Financial data, including grain prices and herbicide costs, were readily available from published sources.

In this study two scenarios will be examined. The first scenario assumes that 2,4-D use is no longer permitted and that farmers do not substitute any other weed control measures. The second case involves examining the effect of a 2,4-D use prohibition if alternative weed control measures are taken. In the analysis, the estimates will be made on a regional basis (eastern and western Canada) and by crop (wheat, barley, and oats), and then aggregated to give the national effect.

While budgeting analysis is commonly used and useful in making individual firm and farm management decisions, it has some limitations when aggregated to a national level that should be clearly recognized. It cannot be used to predict changes in cropping or planting decisions made in response to a pesticide cancellation, nor does it allow one to predict possible changes in either pesticide prices or commodity prices as a result of the cancellation. The extent to which such changes would take place may

alter the results obtained in this study. The results obtained here, however, should be valid for the short run, that is, before all adjustments have taken place. Possible changes in planting decisions and pesticide and grain prices will be discussed in a later section of this study.

Yield Data

The question of the change in crop yields that results from 2,4-D use is very important when calculating 2,4-D benefits. The sensitivity of the results to the yield values used is often ignored or glossed over in pesticide studies. It is desirable, therefore, to obtain as good an estimate as possible for this yield change, using all available data. Consequently, this study will use various approaches to estimate the yield-augmenting effect of 2,4-D.

In examining the yield effects of 2,4-D it may not be sufficient to consider this factor in isolation. Rather, an integrated evaluation should be made that takes into consideration the interrelationship of 2,4-D with other crop production inputs, primarily other herbicides and fertilizer. For example, the introduction of other herbicides to control weeds not controlled by 2,4-D has served to increase the effectiveness of 2,4-D. Experimental evidence suggests that weed species compete with each other as well as with the crop. [13] The removal of susceptible weed species with a selective herbicide that allows resistant species to remain may have little benefit for the crop because of the non-additive effect of weed competition. Thus the use of 2,4-D in combination with another herbicide serves to broaden the range of controlled weeds and the resulting yield increase may be more than the sum of the two herbicides' separate effects on yields. Data for 1979 indicate that approximately 36% of 2,4-D used was as part of a specialty mix or as a tank-wagon mix with another herbicide. [14] Moreover, survey data for Manitoba for 1979 indicated that approximately 40% of wheat and barley acreage received more than one application of herbicides (excluding mixtures). [15] Generally, one treatment was for control of wild oats and grassy weeds and the other for that of broad-leaved weeds. Thus the advent of various other selective herbicides has served to increase the effectiveness of 2,4-D in grain production, rather than to detract from it. Unfortunately data for an integrated evaluation are limited and consequently an examination of 2,4-D in isolation is all that is possible here.

TABLE 5. 2,4-D USAGE IN WESTERN CANADA

Province	2,4-D Ester		2,4-D Ester (low vol.)		2,4-D Amine		Total 2,4-D		MCPA	
	1976-78 average	1979	1976-78 average	1979	1976-78 average	1979	1976-78 average	1979	1976-78 average	1979
	tonnes									
Manitoba	52.4	53.1	28.0	66.1	541.5	534.7	621.9	653.9	570.9	578.5
Saskatchewan	1018.0	984.9	478.4	706.2	581.6	741.6	2078.1	2432.6	484.8	590.9
Alberta	318.4	337.3	178.9	196.0	250.6	276.4	747.9	809.7	712.3	780.5
British Columbia	3.0	3.8	1.0	10.1	3.5	4.7	7.6	18.6	6.6	6.4
Total	1391.8	1379.1	686.3	978.4	1377.2	1557.4	3455.5	3914.8	1774.6	1956.3

Source: M. Daciw, Agriculture Economics Branch, Manitoba Department of Agriculture

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[13] Alex, J.F., "Competition of Saponaria Vaccaria and Sirapis Arvensis in Wheat," Canadian Journal of Plant Science, 50 (1970): 379-388

[14] Thomas, A.G., personal communication, Agricultural Canada Research Station, Regina, Saskatchewan

[15] Thomas, A.G., *1979 Manitoba Weed Survey Questionnaire Data,* Agriculture Canada, 1980

TABLE 6. ONTARIO 2,4-D USAGE 1978

Crop	Formulation	Area Treated	2,4-D Applied
		kha	tonnes of active ingredient
Corn	2,4-D amine	41.1	24.8
	Kilmor	18.0	9.7
Grains	2,4-D amine	240.0	130.0
	Kilmor	8.6	8.0
Hay	2,4-D amine	2.2	1.7
Pastures	2,4-D amine	1.4	.8
All vegetables	2,4-D amine	–	.3

Total phenoxy herbicides used (all field crops, fruits, vegetables, roadsides)

Herbicide	tonnes of active ingredient
2,4-D	157.2
2,4-DB	30.3
MCPA	97.1
MCPB	14.0
Kilmor	17.7 (11.5, 2,4-D)
2,4-D+2, 4-DP+2,4,5-T[1]	74.7

[1] Used in roadside spraying

Source: Roller, N.F., *Survey of Pesticide Use in Ontario, 1978, Ontario* Ministry of Agriculture and Food, Economics Branch, 1979

TABLE 7. PROVINCIAL USE OF 2,4-D FOR FORESTRY AND BRUSH CONTROL (1980-81)

Province	Amount
	tonnes of acid equivalent
Nova Scotia	14 - 27
New Brunswick	36 - 73
Quebec	18 - 36
Ontario	68 - 136
Manitoba	2 - 5
Saskatchewan	.3 - .6
Alberta	.3 - .6
British Columbia	23 - 45
Total	162 - 323

Source: Estimates by Canadian Forestry Service, Environment Canada

The first approach used to obtain yield data was to survey a number of experts in the area of weed science for their opinion on the expected yield increase from using 2,4-D. The opinions indicated that yield increases could range from 5 to 20%. The experts could not give a more precise estimate because of the number of factors involved which affect the effectiveness of the herbicide. The main factors include quantity and variety of weeds present, weather and moisture conditions, time of spraying, and time of weed emergence. These factors vary from year to year, and consequently the effectiveness of 2,4-D can also be expected to vary from year to year.

Using data from experimental test plots was another approach used. A survey was made of data reported by the Expert Committee on Weeds (Western Canada Section and Eastern Canada Section). These reports contain the results of field plot tests, which compare yields on plots treated with various herbicides and untreated check plots, with all other factors equal. Results of plot tests where 2,4-D was used were tabulated for the period from 1947 to the present, for wheat and barley. The results were averaged and are

TABLE 8. AVERAGE YIELD DATA FOR WHEAT AND BARLEY IN WESTERN CANADA AND ONTARIO

Period	Western Canada Wheat	Western Canada Barley	Ontario Wheat	Ontario Barley
	kg/ha			
1910-19	1137	1356	1480	1571
1920-29	1143	1318	1627	1684
1930-39	841	995	1654	1619
1940-49	1103	1280	1870	1668
1950-59	1358	1480	2206	1991
1960-69	1459	1754	2569	2475
1970-79	1769	2233	3026	2695

Sources: Statistics Canada, *Handbook of Agricultural Statistics,* Part I, Field Crops, Catalog No. 21-516
Statistics Canada, *Field Crop Reporting Series No. 20,* Catalog No. 22-002

as follows: [16] For the prairie provinces the average increase in spring wheat yield from plots using 2,4-D, when compared with untreated plots, was 21.3% (based on 28 trials) and the average increase in barley yield was 14.1% (based on 15 tests). For Ontario, the results indicate a 4.1% yield increase in winter wheat (4 tests) and a 12.1% yield increase in barley (8 tests).

The results of the plot tests were highly variable, indicating the effects that the factors mentioned earlier have on the effectiveness of a herbicide. For example, for spring wheat in the prairie provinces the results ranged from a decline in yield of 19.5% to an increase in yield of 96.7% compared to untreated check plots. Generally, low yield increases (or decreases) were noted in test plots with low concentrations of broad-leaved weeds, and high yield increases were noted in very weedy plots, as would be expected. The range of the results from the plot tests would be indicative of the range an individual farmer might get and illustrates the difficulty in estimating the effect of 2,4-D on crop yields. Moreover, the average test plot results should be viewed with caution as they would show higher yield increases than could be expected on the average farm because weed populations in farm fields are not as uniform and fertility levels are usually not as high. Also, test plots might receive better timed pesticide application and greater accuracy in deposition of herbicide than on an operating farm.

[16] In instances where both the ester and amine formulations of 2,4-D were used in the experiment the yield results were averaged. In instances where more than one concentration level of 2,4-D was tested, the 0.56 kg/ha application yield figures were chosen, where available.

Friesen and Shebeski conducted a study in 1956-58 on a sample of operating farms in the Winnipeg area to measure losses due to weeds and the effects of spraying with 2,4-D. [17] Their results indicated a 5.7% increase in wheat yield and a 4.4% increase in barley yield on fields sprayed with 2,4-D. The sample size for the test was relatively small, 28 farms. They also found that the average reduction in crop yields due to weeds over the three-year period of their study was 15.3%. Because of the small sample size and the specific area involved, these results cannot be generalized to a larger region, such as the prairies, although they do give an indication of the benefits that can be expected under the given conditions.

Another possible approach to this question is to examine historical yield data to see if it is possible to isolate the impact of 2,4-D. Table 8 presents 10-year average yield data for wheat and barley in western Canada and Ontario. It will be noted that average wheat and barley yields did not increase significantly until 1950-59, the period following the introduction of 2,4-D. Average yields have continued to increase since then.

An examination of historical data is fraught with problems, as a number of factors are involved which could lead to increases in yield. The factors involved include the following:

- systematic changes in weather conditions;
- changes in crop rotation and changes in summerfallow use;
- increased use of chemical herbicides;
- better fungicides and insecticides to aid in the control of disease and pest outbreaks;
- greater mechanization;

[17] Friesen G. and L.H. Shebeski, "Economic Losses Caused by Weed Competition in Manitoba Grain Fields; I. Weed Species, Their Relative Abundance and Their Effect on Crop Yields." *Canadian Journal of Plant Science,* 40 (1960): 457-467

— better plant varieties being used; and
— a negative factor — the depletion of soil nutrients over time and an increase in soil salinity.

With at least eight factors at play on yield effects, any attempt to separate out the effects of 2,4-D on historical yields will certainly be imprecise. Nevertheless, an illustrative calculation was done for prairie wheat yield changes comparing the 10-year periods 1938-47 and 1950-59, periods just before and just after introduction of 2,4-D. [18] Based on the available data and a number of assumptions, it was estimated that use of 2,4-D could have increased wheat yields by approximately 13% (See Appendix for calculations). The calculation is imprecise because of the large number of factors involved and should only be taken as suggestive of the yield effect which may be obtained from using 2,4-D. Nevertheless, the estimate is consistent with other data and falls within the 5-20% range.

The calculation to determine the minimum yield increase necessary to induce farmers to use 2,4-D may be made. An examination of historical data concerning the quantity of 2,4-D sold indicates that, with fluctuations, 2,4-D use quickly increased and then remained constant over time. It is thus reasonable to assume that farmers have recognized that the benefits of 2,4-D use exceed the cost.

Again taking wheat on the prairies as an example, the average cost of applying 2,4-D on one hectare of crop for the period 1978-80 period was approximately \$5.60 (\$2.50 for the herbicide and \$3.10 application cost). Assume that a farmer would continue to apply herbicides only if returns from its use consistently exceeded costs. Taking a margin of 25% over herbicide and application costs, [19] a farmer must receive an increase in returns of at least \$7.00/ha in order to justify spraying with 2,4-D. The average price that a farmer received for No. 1 C.W. Red Spring Wheat during the 1977-80 period was \$0.158/kg. Consequently, wheat yields had to be increased by 44 kg/ha for a farmer to justify spraying. Based on a 20-year average yield of 1615 kg/ha, wheat yields would have had to increase by 2.7% to induce the farmer to spray. Thus we can say that as a minimum figure, 2,4-D use increased yields by at least 3%. This assumes that all farms have similar weed concentrations. However, on farms with higher weed concentrations the yield effect will be larger. Consequently, the average yield increase would be expected to be much larger than 3%.

[18] While some 2,4-D was used in 1947, the amount was too small to affect overall yield. The years 1948-49 were not used as they were transition years.

[19] The herbicide and its application costs do not represent the total cost to the farmer. The 25% margin is to acknowledge (in a subjective estimate) that other costs, such as the farmer's management time, a risk factor, etc. are associated with the use of herbicides.

In light of the difficulty in obtaining an accurate figure for the yield increase attributable to 2,4-D, it was decided to use the figure of a 10% yield change to calculate the benefits of 2,4-D for small-grain production in Canada. The 10% figure is attractive in that one can double or halve the results obtained to obtain the 5-20% range.

It is likely that the 10% figure is not strictly applicable to all crops and regions. For some crops and regions, the figure might be higher while for others (likely eastern wheat) the figure would be lower. Thus, it should be considered as an average figure for all grain. Furthermore, the figure should be considered as applying to the short run. Following a 2,4-D use restriction it is expected that the population of weeds susceptible to 2,4-D would increase and thus a figure larger than 10% would be appropriate. Lack of long-term data precludes any estimation of these effects over time.

All approaches examined were consistent with the 5-20% range. Furthermore, all approaches tended to suggest that a central value such as 10% would be appropriate. Test plot data suggested the upper value of 20%; however, plot data seem to overestimate the effects. An experiment on farms and economic considerations of use suggest the lower value of 5%; however, here the data seem to understate the effects. The 10% value, of course, would be for an average year as yearly effects could vary from 5% to 20%, depending on the weather and other factors.

Impact of 2,4-D Non-Availability on Grain Crops

The primary effect of the non-availability of 2,4-D will be on grain yield and quality. In the previous section, the use of 2,4-D was explored in some detail. In this section, an estimate will be made of the dollar value of the benefits of 2,4-D use on grain crops for the year 1979. This year is being used because it is the most recent one for which utilization data, as well as others, are available.

First, an estimate will be made of the value of 2,4-D in grain production by assuming that no replacement herbicide is used for 2,4-D and no changes in cropping take place. Next, an examination will be made of the additional costs associated with a 2,4-D cancellation due to use of more costly or less effective herbicides as replacements for 2,4-D.

Impact on Grain Production, With No Substitution for 2,4-D

In this section an estimate is made of the "pure" benefit of 2,4-D. It was difficult to calculate this benefit because comprehensive use data were lacking. While the total area to which 2,4-D was applied can be derived from using 2,4-D sales and recommended utilization rates, the proportions of each crop that were sprayed with 2,4-D are also required. Survey

TABLE 9. ESTIMATED AREA SPRAYED WITH 2,4-D IN WESTERN CANADA, BY CROP

Grain	Area Seeded[1]	Estimated Sprayed[2]	Estimated Area Sprayed	Sprayed 2,4-D Alone[3]
	kha	%	kha	%
Wheat	10 231	56.6	5 786	61
Barley	3 533	48.0	1 696	76
Oats	1 146	31.1	356	70
Mixed grains	196	N.A.	–	–
Rye	296	N.A.	–	–
Total	15 403		7 835	

[1] Source of data: Statistics Canada, Field Crop Reporting Series No. 20, Cat. No. 22-002

[2] Based on 1979 weed survey data for Manitoba and Saskatchewan, provided by A.G. Thomas, Regina Research Station, Agriculture Canada. Survey data were assumed to apply also to Alberta and British Columbia seeded area. Survey results were adjusted downward on a weighted average basis in order that the estimated sprayed area agreed with the area assumed to have been sprayed (based on recommended application rates).

[3] Based on 1979 weed survey data for Manitoba and Saskatchewan, provided by A.G. Thomas, Regina Research Station, Agriculture Canada

data for 1979, obtained from A.G. Thomas, Agriculture Canada Research Station, Regina, Saskatchewan, for the provinces of Manitoba and Saskatchewan, provided an estimate of the percentage to which the major crops were sprayed with 2,4-D. For this study, the figures given in Table 9 are assumed to apply to the crop area in all four western provinces. The survey results had to be adjusted downwards on a weighted average basis in order that the estimate of the sprayed area agreed with the area that was assumed to have been sprayed (based on 2,4-D sales and recommended application rates). Also presented in Table 9 are data on the percentage of area sprayed using 2,4-D alone, the remaining percentage being 2,4-D applied in a mixture with another herbicide.

While it is recognized that this manner of using the survey results may be subject to error, we believe that using the estimate obtained was preferable to assuming, for example, that the same percentage of each crop was treated with 2,4-D. Nevertheless, sensitivity calculations using the same-percentage assumption, among others, indicated that final values would be less than 3% different than the values given in Table 9.

Based on the crop usage levels, as shown in Table 9, a calculation was made of the total benefits of 2,4-D. Table 10 presents the estimated crop losses due to the unavailability of 2,4-D and the decision not to use any alternative weed control measures. The estimates indicate that in 1979 2,4-D use increased small grain production in Canada by 1.3 Mt with a gross value of $214 million. The net value of the increased production was $176 million, after substracting $38 million for herbicide and application costs. Of the $214 million gross value, $163 million (76%) was due to increased wheat production in western Canada. The value of 2,4-D net benefits represents 6.0% of the value of farm receipts for wheat, barley, and oats in 1979 and 5.0% of total net farm income in Canada. [20]

The Effect of Using Alternative Herbicides on Production and Costs

The true measure of the cost of prohibiting 2,4-D use is the additional costs associated with alternative pesticides and weed control methods. Without additional data it is, however, difficult to predict the changes farmers would have to make in their choice of herbicides, cultural practices, and cropping practices if 2,4-D use were to be prohibited. Moreover, relative efficacies of various herbicides are difficult to quantify, given the different range of weeds they control. Nevertheless, with the use of some simplifying assumptions it is possible to obtain a crude estimate of the costs associated with alternative pesticide use.

Should 2,4-D be unavailable, the most likely substitute is MCPA, another phenoxy herbicide. As MCPA is chemically similar to 2,4-D, it can be assumed to be equally effective in controlling broadleaved weeds, and thus increasing grain yield. The historical increase in the use of MCPA relative to 2,4-D, despite its slightly higher price, supports the assumption that MCPA is as effective as 2,4-D. Therefore, based on 1979 treatment costs of approximately $1.20/ha more for MCPA than for 2,4-D, the use of MCPA would have increased farmers' input costs by $8.9 million.

[20] Statistics Canada, *Farm Net Income,* Catalog No. 21-202

TABLE 10. ESTIMATED LOSSES IN GRAIN PRODUCTION FOR 1979 DUE TO UNAVAILABILITY OF 2,4-D

Region	Crop	Hectares Treated[1]	Application Cost[2]	Yield Losses Weight[3]	Yield Losses Value[4]	Net Loss[5]
		kha	$'000	kt	$'000	$'000
Western Canada	wheat	3 529	19 233	562.2	110 192	90 959
		2 257	7 448	269.7	52 861	45 413
	barley	1 289	7 025	288.0	30 816	23 791
		407	1 343	68.2	7 297	5 954
	oats	249	1 357	47.1	3 203	1 846
		107	353	15.2	1 034	681
Eastern Canada	small grains	240	1 308	69.0	8 280	6 972
		9	30	1.9	228	198
Total		8 087	38 097	1 321.3	213 911	175 814

[1] Data for western Canada were taken from Table 9. Data on 2,4-D used alone and 2,4-D used in a mixture are treated separately. Data for eastern Canada are essentially 1978 Ontario data (Table 7). It is assumed that the area treated was approximately the same in 1979 and that area treated in the Maritime provinces and Quebec is extremely small.

[2] Using a herbicide cost of $2.35/ha plus an application cost of $3.10/ha for 2,4-D alone and a herbicide cost of $1.75/ha and $1.55 application cost for 2,4-D in mixtures.

[3] Based on a 10% yield loss on area treated with 2,4-D alone and a 7.5% yield loss on area treated with 2,4-D in mixtures with other herbicides.

[4] The following values of grain for 1979-80 were used: wheat $196/t, barley $107/t, oats $68/t, small grains $120/t (weighted average 1979 price for all small grains in Ontario).

[5] Yield loss value less application cost.

A difficulty with MCPA is that it is chemically similar to 2,4-D; thus it is possible that its use may also be curtailed in the event that 2,4-D use were prohibited. Thus, the effect on production and input costs should also be based on the assumption that both phenoxy herbicides, 2,4-D and MCPA, are not available.

Alternatives to the phenoxy herbicides are limited. Two herbicides, bromoxynil and dicamba, are used in broad-leaf weed control, but to a much lesser extent than 2,4-D or MCPA. Of the two, bromoxynil would be more effective as dicamba does not control major annuals such as members of the mustard family and requires a more specific timing of application with respect to crop stage. Bromoxynil controls a number of broad-leaved weeds but not all species of mustard, nor as many different species of weeds as 2,4-D. It is also significantly more expensive. It is difficult to estimate the effectiveness of bromoxynil relative to 2,4-D as both herbicides control a somewhat different range of weeds. In fact, when bromoxynil is used, it is usually done in combination with MCPA to increase the range of weeds controlled. While it appears that bromoxynil is less effective than 2,4-D, a reliable estimate of its relative effectiveness is not available.

Should use of phenoxy herbicides not be permitted, farmers would have a number of alternatives which include

— to use bromoxynil instead of the phenoxy herbicides and incur the higher treatment cost and possibly lower yields;
— not to use any broad-leaved weed herbicides but use cultural practices, and incur some yield losses; or
— to use less expensive, but also much less effective herbicides than bromoxynil, such as dicamba.

It is difficult to estimate how farmers would react to a phenoxy herbicide cancellation; hence, the measurement of additional costs is complicated. A solution to this problem is to choose the best apparent alternative, and assume that the other choices would lead to equal or greater costs due to production losses or higher input costs or both. I assumed that the best alternative is to use bromoxynil. Because there are no comparative efficacy data, I also assumed that in the short run [21] bromoxynil is as effective as 2,4-D in increasing grain yields.

Table 11 contains a calculation of the increase in the cost of treating fields with bromoxynil rather than phenoxy herbicides. For 1979 this increased cost is $46 million on the crop area treated with 2,4-D and $66 million when the MCPA-treated area is added. This latter value would represent an 18.6% increase

[21] Here the short-run refers to two to three years; that is, before the weed population susceptible to 2,4-D but not to bromoxynil begins to build up and leads to larger grain yield losses.

TABLE 11. INCREASE IN INPUT COSTS DUE TO USING BRONOXYNIL RATHER THAN PHENOXY HERBICIDES, 1979

Herbicide Treatment	Area Treated[1]	Increased Treatment Cost[2]
	kha	$'000
2,4-D alone	5 307	32 373
2,4-D mixtures[3]	2 780	13 900
MCPA alone	1 494	7 321
MCPA mixtures[3]	2 919	11 968
Total	12 500	65 562

[1] Total small grain in Canada treated with phenoxy herbicides. 2,4-D data taken from Table 10, MCPA data developed from same sources as 2,4-D data.

[2] Area treated is multiplied by the difference in cost between 2,4-D or MCPA and bromoxynil. The following 1979 costs were used: 2,4-D alone $2.35/ha, in mixtures $1.75/ha; MCPA alone $3.55/ha, in mixtures $2.65/ha; bromoxynil alone $8.45/ha, bromoxynil in mixtures $6.75/ha.

[3] Bromoxynil is the other herbicide used in some 2,4-D mixtures and to a greater extent in MCPA mixtures (numerical estimates unavailable). Consequently, some double counting will occur here as farmers will not spray twice as much bromoxynil to compensate. Nevertheless, for this exercise it can be assumed that if another herbicide (e.g., dicamba) or no herbicide were used in place of the phenoxy, the additional herbicide cost and yield losses would equal or be greater than the cost increase if additional bromoxynil could be used.

in farmers' expenditures on pesticides for 1979.[22] Based on the assumptions, it is thus estimated that if phenoxy herbicides were not available, farm input costs or value of grain production losses due to weeds or both would increase by at least $66 million and possibly much more, depending on the efficiency of the substitute herbicides.

The above discussion assumes that no new herbicides are forthcoming. However, research on new herbicides is continuing, and it is possible that suitable substitutes for 2,4-D may become available.

Effect on Other Factors of Grain Production

Besides yield, other factors associated with weed growth in grain crops might also be affected if 2,4-D use were to be prohibited, namely, dockage, grain quality (grade and protein content), and harvesting costs.

Dockage

"Dockage" is a term used to refer to the foreign material contained in harvested grain, which can be removed with approved cleaning equipment. This foreign material includes broken grains, weed seeds, chaff, hulls, dirt, and other foreign materials. The level of dockage does not affect the grade assigned to the grain. In some cases, however, the presence of inseparable weed seeds is a degrading factor (an example is wild oats in feed barley). On receipt of any grain at the country elevator, dockage is calculated and deducted from the total weight of grain delivered. The farmer receives payment only for the net amount of graded grain delivered. Also, he pays handling and freight only on the net tonnes delivered. It is at this point that the dockage becomes the property of the grain company.

Dockage is removed from grain during the cleaning process at the terminal elevators. Once removed from grain, dockage is termed "screenings." Screenings are sold by the grain companies as animal feed and for other uses. The revenue from the screenings serves to offset the cost of cleaning the grain.

Many consider dockage as a direct cash loss to the farmer, as it appears that he or she is losing a proportion of grain. However, it is not correct to calculate dockage as a direct loss of income to the farmer. The real loss occurred in the field as yield reduction due to weed competition. To count dockage as a loss would result in double counting. The only costs of the farmer that can be attributed to dockage are the extra costs of storing and handling this foreign material along with the grain.

While an increase in dockage levels would add little in terms of extra costs, an examination of whether 2,4-D had any effect on dockage levels will still be made. Historical data on dockage in grain delivered to terminal elevators are available and 10-year average values are presented in Table 12. Most western Canadian grain is cleaned at the terminal elevators. For the period following the introduction of 2,4-D in 1947 and subsequently other herbicides, the percentage of dockage has not decreased but has remained at about 2.5% for wheat. In fact, there appears to have been a small average increase in the dockage level of wheat in the herbicide era.

[22] *Farm Net Income, op. cit.*

TABLE 12. AVERAGE DOCKAGE ON WHEAT AND BARLEY AT TERMINAL ELEVATORS

Period	Dockage Wheat	Dockage Barley
	%	
1920-29	2.07	.94
1930-39	2.05	.78
1940-49	2.35	1.47
1950-59	2.48	1.48
1960-69	2.51	1.21
1970-79	2.56	1.27

Source: Statistics Canada, *Grain Trade of Canada,* Catalog No. 22-201

The result is contrary to what one might at first expect. The method of measuring dockage has not changed during the 1920-79 period. [23] While data on the composition of dockage might provide some insight, unfortunately they are not available. Some information, however, is available concerning screenings. A comparison of discussions of grades of screenings by Manson [24] (1932) and Owen [25] (1972) seem to indicate that little has changed in the composition of screenings between these two periods. In both periods screenings apparently consisted primarily of broken grains, wild oats, and wild buckwheat (these two weeds are not controlled by 2,4-D). Mustard seed and small weed seeds appear to comprise only a small part of screenings since the advent of chemical herbicides, and while they used to be present in higher concentrations still represented only a small part of the screenings.

In a study of 660 uncleaned grain samples from Manitoba in 1974, Chow and Lapka [26] found that of the 2.2% dockage in wheat, 1.6% was composed of weeds, while for barley the figure was 3.9% dockage and 2.7% weed seeds. The remaining material would be broken grain, volunteer crop grain, and chaff. The percentage of weed seeds found in the samples may be somewhat high since a prairie average is estimated to be about 50% of screenings. [27] Chow and Lapka found the two major weed seeds present to be wild oats and green foxtail, with small amounts of others.

[23] *Fast, H., personal communication, Deputy Director, Grain Inspection Division, Canadian Grain Commission*

[24] *Manson, J.M., "Weed Survey of the Prairie Provinces," Publication No. 1 of the Associate Committee on Weed Control,* 1932, in Collected Papers of the Associate Committee on Weed Control 1932-37, National Research Council of Canada

[25] Owen, C.H., "Study of Problems Associated With Weed Seeds in Grain," 1972, an unpublished study for the Canadian Grain Commission

[26] Chow, P.N.P. and W.J. Lapka, "Dockage in Grain Samples in Manitoba," *Annual Conference of Manitoba Agronomists Technical and Scientific Papers,* 1975, pp. 133-137

[27] Fast, H., *op. cit.*

It may be possible that historically some factors have systematically affected dockage levels. For example, more weedy grain may have been fed to livestock in earlier years than at present, or changes in grain threshing equipment may have affected the cleanliness of grain coming off the field. Data on such possible factors are not available.

The available evidence indicates that the introduction of 2,4-D has had such a small effect on the level of dockage that should 2,4-D become unavailable, the effect on dockage levels would also be minor. It is expected that there would be an increase in the proportion of weed seeds susceptible to 2,4-D in it.

Grain Quality

Two aspects of grain quality are important: its grade and protein content. Grade is determined by a number of factors, one of which is the presence of inseparable weed seeds. For 1970, it was estimated that 0.6% of wheat and 7.3% of barley sold were reduced in grade by inseparable weed seeds. [28] The latter generally come, however, from weeds that are not susceptible to 2,4-D such as wild oats and tartary buckwheat so that 2,4-D use should not have any effect on this grading factor. Moreover, Burrows and Olson [29] reported that 2,4-D use did not affect the grade of wheat.

Protein content is an important quality factor. The Canadian Wheat Board sells wheat on a guaranteed protein level basis, and higher prices are received for wheat with a higher protein level. Research indicates that removal of weeds from grain crops increases the

[28] Owen, C.H., 1972, *op. cit.*

[29] Burrows, V.D. and P.J. Olson, "Reaction of Small Grains to Various Densities of Wild Mustard and the Results Obtained After Their Removal With 2,4-D or by Hand," *Canadian Journal of Agricultural Science,* 35 (1955): 68-75

protein content of the grain. [30] Several investigators have found that treatment with 2,4-D, or other herbicides, results in increased protein content, [31] although one researcher found no significant change in wheat protein levels on plots treated with 2,4-D. [32] While research generally indicates that 2,4-D use has a positive effect on grain protein, the magnitude of this effect is difficult to extrapolate from plot data, especially when one takes into consideration the interrelationships among the factors that affect protein content, such as weather conditions and nitrogen fertilizer use. Nevertheless, an illustrative calculation can be made, using the experimental data, of the increased value of wheat due to its higher protein content. Barley is not sold on the basis of protein level, so no calculation will be made for it. Furthermore, while it is desirable to have higher protein levels for barley used as feed, barley for malting purposes requires lower protein levels.

Data from Friesen et al [33] will be used because their experiment was done on sample farms in the Winnipeg area. They found that controlling weeds increased protein levels in grain by 0.24 percentage points. Using this factor weighted by the proportion of wheat area treated with 2,4-D, it is possible to calculate the loss in the value of wheat that would result from a drop in its protein level. The results of such a calculation are presented in Table 13. They indicate that for 1979 the value of Canadian wheat sales would have been reduced by $4 million due to the lower protein levels that would have resulted had 2,4-D not been used and another herbicide not replaced it.

Harvesting Costs

While it is expected that harvesting costs might be higher if weeds are present in the crop, data measuring such costs are limited. The increased costs might arise from greater combine harvest grain losses and less efficient operation of harvesting equipment (e.g., slower ground speed used). In an experiment conducted in Ohio, McCuen and Silver [34] found a 4% combine harvest loss in clean small grains and a 13% loss in weedy ones. In their experiment, the grain was harvested while it was still standing and the weedy material still green. The common practice in the prairie provinces, however, is to windrow the grain before threshing it, thereby dessicating the weeds before harvesting. In a study of harvesting efficiency in corn, sorghum, and soybeans, Burnside *et al* [35] found that when the weeds had been desiccated in the field by freezing, the efficiency of combine harvesting was not affected. There are no Canadian data on this question but the opinion of a researcher in the area of harvesting losses is that under present practices, harvesting losses due to the presence of weeds are minimal. [36] Consequently, should 2,4-D not be available and no suitable replacement were to be used, he believes that the increase in harvesting costs would be small. Experimental studies are needed to determine the validity of this assumption.

Other Economic Effects

In addition to a loss in the value of grain production and an increase in pesticide input costs, a 2,4-D use cancellation has a number of other economic implications. They relate to the effect on farmers and herbicide suppliers, as well as the Canadian economy in general. The magnitude and direction of these effects, however, depends on the circumstances under which a 2,4-D use prohibition in grain production occurs. For example, the economic effects can vary significantly depending on whether Canada acts alone in prohibiting 2,4-D use or the United States and other grain exporting countries act similarly.

Effect on Farm Income

The reduction in crop yields and increase in input costs that a 2,4-D prohibition entails would certainly affect farm income. The magnitude of the effect would depend on several factors, including whether Canada acts alone and what price adjustments would take place.

If Canada acted alone, the effect on farm income would be greater than if the United States and other countries were to take similar action. Prices for Canadian grain are determined in international markets. This is verified by econometric studies,

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[30] Friesen, G., L.H. Shebeski and A.D. Robinson, "Economic Losses Caused by Weed Competition in Manitoba Grain Fields. II Effect of Weed Competition on the Protein Content of Cereal Crops," *Canadian Journal of Plant Science,* 40 (1960): 652-658; and Mayer, J.R. and R.D. Dryden, "Effects of Combined Applications of Triallate or Trifluralin With Solution Nitrogen on Wheat, Wild Oats and Green Foxtail," *Canadian Journal of Plant Science,* 57 (1977): 479-484

[31] Aitkin, T.R., W.O.J. Meredith, and P.J. Olson, "Effects of 2,4-D on Quality of Western Canadian Wheat, Barley and Oats," *Scientific Agriculture,* 32 (1952): 317-332; Burrows, V.-D. and P.J. Olson, 1955, *op. cit.;* Engstrom E., "Influence of Weed Control on the Protein Content of Cereals," *Weeds and Weed Control, 15th Swedish Conference,* 15 (1974): E1-E2; and Mayer, J.R. and R.D. Dryden, 1977, *op. cit.*

[32] Hill, K.W., "Protein Content of Wheat as Affected by Agronomic Practices", *Canadian Journal of Plant Science,* 44 (1964): 115-122

[33] Friesen *et al.,* 1960, *op. cit.*

[34] McCuen, G.W. and E.A. Silver, "Combine Harvester Investigations," *Ohio Agriculture Experimental Station Bulletin,* 1943, p. 643

[35] Burnside, O.C., G.A. Wicks, D.D. Warnes, B.R. Somerhalder and S.A. Weeks, "Effect of Weeds on Harvesting Efficiency in Corn, Sorghum, and Soybeans", *Weed Science,* 17 (1969):438-441

[36] Clarke, J.M., personal communication, Agriculture Canada Research Station, Swift Current, Saskatchewan

TABLE 13. ESTIMATED VALUE OF LOSS IN WHEAT QUALITY DUE TO UNAVAILABILITY OF 2,4-D

CWRS Grade	Protein Content		Exports[1]	Protein Grade Loss[2]	Price Differential[3]	Value Lost
			kt	kt	$/t	$'000
1	15	W[4]	91	10.9	5.55	60.5
		E[5]	11	1.3	6.47	8.4
	13.5	W	1 747	209.6	4.33	907.6
		E	1 833	220.0	4.33	952.6
	12.5	W	633	76.0	5.00	380.0
		E	1 525	183.0	5.00	915.0
	11.5	W	9	[6]	–	–
		E	25	–	–	–
2	13.5	W	–	–	–	–
		E	385	46.2	6.00	277.2
	12.5	W	1 072	128.6	5.38	691.9
		E	413	49.6	3.00	148.8
	11.5	W	193	23.2	–	–
		E	31	3.7	–	–
					Total	4 342.0

[1] Source: Canadian Grain Commission, 1980, Canadian Grain Exports, crop year 1979-80.

[2] Protein grade loss is the volume of exports multiplied by the factor 0.12. The factor 0.12 is derived from using 0.24% protein content decrease weighted by percent 2,4-D usage in wheat. It is assumed that within each protein level the protein content is uniformly distributed.

[3] Price difference between higher and lower protein levels for crop year 1979-80.

[4] W refers to western Canadian ports.

[5] E refers to eastern Canadian ports.

[6] It is assumed that no reduction in the 11.5% protein level would occur.

Source: Canadian Wheat Board.

which found that excess demand for wheat is price elastic. [37] What this means is that if Canada were to increase its price of wheat above prevailing world price levels, export sales would drop considerably. However, as Canada has some market power in wheat sales, a drop in its wheat supplies (due to lower yields) could be expected to increase world wheat prices slightly. The net result would be that grain producers would bear the brunt of increased costs through reduced farm returns, while grain consumers would pay a small portion of these costs through slightly higher grain prices. For most of the regions where grain is grown, the possibility of farmers switching to economically viable crops that do not depend on 2,4-D treatment is limited. Consequently, despite the lower returns from grain production if 2,4-D is not available, farmers would be expected to decrease their grain acreage by only a small amount.

[37] Nagy, J.G., W.H. Furton and S.N. Kulshreshtha, *The Canadian Wheat Economy: Economic Implications of Changes in the Crowsnest Pass Freight Rates,* 1979, Department of Agricultural Economics, University of Saskatchewan; and MacLaren, D., "Canadian Wheat Exports in the International Market: An Exploratory Economic and Policy Analysis," *Canadian Journal of Agricultural Economics,* 25 (1977):1 31-54

The situation is somewhat different if other countries, especially the United States, act to prohibit 2,4-D use. In this situation, world wheat production would decrease and prices for grain would increase, assuming other factors remain constant. Depending on the extent to which prices rise, Canadian producers could be compensated for their increased costs, thereby maintaining farm income levels. In this case consumers, mainly foreign in the case of wheat, would bear the brunt of 2,4-D cancellation costs.

Effect on Herbicide Suppliers

The pesticide industry in Canada consists of about 700 firms that are engaged in one or more aspects of producing, formulating, and distributing pesticides, subject to regulation under the Pest Control Products Act. At present 60 of these firms are suppliers of 2,4-D.

The pesticide industry in Canada is a small sub-sector within the chemical industry sector, accounting for only 1.6% of the total chemical industry shipments in 1979. [38] Employment in the pesticide industry in 1980

[38] Chemicals Branch, Industry, Trade and Commerce, "A Sector Analysis of the Pesticides Industry in Canada," 1981, an unpublished discussion paper

was estimated to be about 1200 for the 22 firms that are responsible for over 90% of the pesticide business activity. [39] Manufacturing activities of this industry in Canada consist of a small amount of production of a pesticide active ingredient and a somewhat larger amount (approximately 30% of the value of registrants' sales) of manufacturing associated with formulating and packaging imported active ingredients into finished products. Over 90% of pesticide active ingredients used in Canada are imported, with nearly 80% of these entering the country in the formulated state. [40]

Data on Canadian manufacturing activities of 2,4-D are not available but may be similar to those on the industry trend. The major effect of a prohibition of 2,4-D use would be on its suppliers since it would result in loss of sales, revenue, and possibly employment. On the other hand, companies that supply replacement herbicides would gain from a 2,4-D restriction. The overall impact on the industry would depend on the extent to which farmers would switch to alternative herbicides. As the demand for pesticides has been found to be price inelastic, [41] farmers can be assumed to be willing to switch to more expensive herbicides if 2,4-D were not available. The extent to which farmers switch would also be governed by the efficacy of alternative herbicides. As the bulk of the pesticide industry formulates pesticides from imported active ingredients or distributes imported formulated products, a large proportion of farmers switching to alternative herbicides should not affect the overall employment and earnings in the industry significantly. As for the retailers, in the prairie provinces herbicides are sold to farmers mainly by grain elevator companies and cooperatives. Pesticide sales form a small part of their revenue so that a restriction on one herbicide would not be a significant problem for them, especially if sales of other herbicides increase.

Canadian use of herbicides represents only 3% of the world market. [42] The consumption period for herbicides in Canada, however, is quite short, generally only one or two months. As a consequence, pesticide suppliers must anticipate demand and have their supplies readily available. It may take a while after one herbicide is banned for suppliers to be able to predict demand reasonably for alternative herbicides. Therefore, temporary shortages or an oversupply situation may result in the first few years following a ban.

Should the United States also restrict 2,4-D use, the situation for Canada would be more critical. The U.S. consumes 33% of world pesticide output and supplies 75% of the pesticides used in Canada. [43] Consequently, Canadian supply of alternative herbicides may suffer appreciably and prices may rise if the United States were also to disallow 2,4-D use.

[39] *Ibid.*

[40] *Ibid.*

[41] *Ibid.*

[42] *Ibid.*

Effect on Energy Use

With increasing energy costs, especially from petroleum-based sources, it is appropriate to examine the consequences of 2,4-D non-availability on energy use. Of the energy used on farms, pesticides represent only about 0.1% of total energy use. [44] Consequently, they are an extremely small part of the energy input into farming.

In examining the energy consequences of a change in policy, the most appropriate method is to consider the amount by which total non-renewable resources are depleted. Resource depletion is said to be equal to the energy value of the fuel being consumed, multiplied by a factor which represents the energy expenditure in the supply system. For example, because of the energy costs of transportation and refining, every 173.4 MJ consumed as 1 L of diesel fuel in a farm tractor engine represents a depletion of 204.5 MJ in the crude petroleum resource at the wellhead. [45]

Data are available on the energy costs of producing 14 different herbicides (Table 14), and data indicate that of these, 2,4-D requires the least energy to produce. This implies that if 2,4-D were no longer available and a switch were made to another herbicide, the energy utilization by society would increase (albeit by an extremely small amount).

As 2,4-D is generally applied post-emergently in grain crops, it is not possible to compare directly its energy consumption to energy use from additional tillage operations. However, in a study of organic versus conventional farming, it was found that without herbicides, an extra one to three cultivations were required for weed control. [46] Table 15 compares the total energy cost of one application of 2,4-D herbicide to those of various tillage operations. The data were developed for Ontario; values may be slighly different in other areas of the country (depending on soil type, etc.). The data indicate that one application of 2,4-D utilizes less energy than any of the tillage operations. For example, 4.4 applications of 2,4-D would equal one discing operation.

[43] *Ibid.*

[44] Timbers, G.E., *Present Use of Energy on Canadian Farms,* 1977, Ottawa, Research Branch, Agriculture Canada

[45] Southwell, P.H. and T.M. Rothwell, *Report on Analysis of Output/Input Energy Ratios of Food Production in Ontario,* 1977, School of Engineering, University of Guelph

[46] USDA Study Team on Organic Farming, *Report and Recommendations on Organic Farming,* 1980, U.S. Department of Agriculture, Washington, D.C.

TABLE 14. ENERGY COSTS OF HERBICIDE MANUFACTURE

Herbicide	Input Energy
	MJ/kg of active ingredient
Paraquat	415
Glyphosate	387
Diquat	369
Dicamba	286
Propachlor	280
Diuron	274
Propanil	212
Atrazine	201
Chloramben	179
Trifluralin	142
2,4,5-T	130
MCPA	129
Dinoseb	91
2,4-D	82

Source: Southwell, P.H. and T.M. Rothwell, *Report on Analysis of Out/Input Energy Ratios of Food Production in Ontario*, School of Engineering, University of Guelph, p. 55, 1977

TABLE 15. SUMMARY OF ENERGY COSTS OF VARIOUS CROP PRODUCTION OPERATIONS

Energy Inputs Per Hectare		ERD(FF)[1] MJ	ERD(T)[2] MJ
Discing (tandem disc)			
Fuel		304.3	304.3
Machinery energy depreciation		180.6	190.2
	Total	484.9	494.5
Cultivating (spring tine)			
Fuel		202.7	202.7
Machinery energy depreciation		138.3	145.6
	Total	341.0	348.3
Harrowing (spike-tooth)			
Fuel		50.8	50.8
Machinery energy depreciation		76.9	81.0
	Total	127.7	131.8
Herbicide			
a) Material: 2,4-D amine (50% active ingredient)		42.5	46.1
b) Application: fuel		50.8	50.8
machinery energy depreciation		16.9	17.5
	Total	110.2	114.4

[1] Energy Resource Depletion (Fossil Fuel)

[2] Energy Resource Depletion (Total)

Source: Southwell, P.H. and T.M. Rothwell, *Report on Analysis of Output/Input Energy Rates of Food Production in Ontario*, School of Engineering, University of Guelph, 1977

was estimated to be about 1200 for the 22 firms that are responsible for over 90% of the pesticide business activity. [39] Manufacturing activities of this industry in Canada consist of a small amount of production of a pesticide active ingredient and a somewhat larger amount (approximately 30% of the value of registrants' sales) of manufacturing associated with formulating and packaging imported active ingredients into finished products. Over 90% of pesticide active ingredients used in Canada are imported, with nearly 80% of these entering the country in the formulated state. [40]

Data on Canadian manufacturing activities of 2,4-D are not available but may be similar to those on the industry trend. The major effect of a prohibition of 2,4-D use would be on its suppliers since it would result in loss of sales, revenue, and possibly employment. On the other hand, companies that supply replacement herbicides would gain from a 2,4-D restriction. The overall impact on the industry would depend on the extent to which farmers would switch to alternative herbicides. As the demand for pesticides has been found to be price inelastic, [41] farmers can be assumed to be willing to switch to more expensive herbicides if 2,4-D were not available. The extent to which farmers switch would also be governed by the efficacy of alternative herbicides. As the bulk of the pesticide industry formulates pesticides from imported active ingredients or distributes imported formulated products, a large proportion of farmers switching to alternative herbicides should not affect the overall employment and earnings in the industry significantly. As for the retailers, in the prairie provinces herbicides are sold to farmers mainly by grain elevator companies and cooperatives. Pesticide sales form a small part of their revenue so that a restriction on one herbicide would not be a significant problem for them, especially if sales of other herbicides increase.

Canadian use of herbicides represents only 3% of the world market. [42] The consumption period for herbicides in Canada, however, is quite short, generally only one or two months. As a consequence, pesticide suppliers must anticipate demand and have their supplies readily available. It may take a while after one herbicide is banned for suppliers to be able to predict demand reasonably for alternative herbicides. Therefore, temporary shortages or an oversupply situation may result in the first few years following a ban.

Should the United States also restrict 2,4-D use, the situation for Canada would be more critical. The U.S. consumes 33% of world pesticide output and supplies 75% of the pesticides used in Canada. [43] Consequently, Canadian supply of alternative herbicides may suffer appreciably and prices may rise if the United States were also to disallow 2,4-D use.

Effect on Energy Use

With increasing energy costs, especially from petroleum-based sources, it is appropriate to examine the consequences of 2,4-D non-availability on energy use. Of the energy used on farms, pesticides represent only about 0.1% of total energy use. [44] Consequently, they are an extremely small part of the energy input into farming.

In examining the energy consequences of a change in policy, the most appropriate method is to consider the amount by which total non-renewable resources are depleted. Resource depletion is said to be equal to the energy value of the fuel being consumed, multiplied by a factor which represents the energy expenditure in the supply system. For example, because of the energy costs of transportation and refining, every 173.4 MJ consumed as 1 L of diesel fuel in a farm tractor engine represents a depletion of 204.5 MJ in the crude petroleum resource at the wellhead. [45]

Data are available on the energy costs of producing 14 different herbicides (Table 14), and data indicate that of these, 2,4-D requires the least energy to produce. This implies that if 2,4-D were no longer available and a switch were made to another herbicide, the energy utilization by society would increase (albeit by an extremely small amount).

As 2,4-D is generally applied post-emergently in grain crops, it is not possible to compare directly its energy consumption to energy use from additional tillage operations. However, in a study of organic versus conventional farming, it was found that without herbicides, an extra one to three cultivations were required for weed control. [46] Table 15 compares the total energy cost of one application of 2,4-D herbicide to those of various tillage operations. The data were developed for Ontario; values may be slighly different in other areas of the country (depending on soil type, etc.). The data indicate that one application of 2,4-D utilizes less energy than any of the tillage operations. For example, 4.4 applications of 2,4-D would equal one discing operation.

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39 *Ibid.*

40 *Ibid.*

41 *Ibid.*

42 *Ibid.*

43 *Ibid.*

44 Timbers, G.E., *Present Use of Energy on Canadian Farms,* 1977, Ottawa, Research Branch, Agriculture Canada

45 Southwell, P.H. and T.M. Rothwell, *Report on Analysis of Output/Input Energy Ratios of Food Production in Ontario,* 1977, School of Engineering, University of Guelph

46 USDA Study Team on Organic Farming, *Report and Recommendations on Organic Farming,* 1980, U.S. Department of Agriculture, Washington, D.C.

TABLE 14. ENERGY COSTS OF HERBICIDE MANUFACTURE

Herbicide	Input Energy
	MJ/kg of active ingredient
Paraquat	415
Glyphosate	387
Diquat	369
Dicamba	286
Propachlor	280
Diuron	274
Propanil	212
Atrazine	201
Chloramben	179
Trifluralin	142
2,4,5-T	130
MCPA	129
Dinoseb	91
2,4-D	82

Source: Southwell, P.H. and T.M. Rothwell, *Report on Analysis of Out/Input Energy Ratios of Food Production in Ontario,* School of Engineering, University of Guelph, p. 55, 1977

TABLE 15. SUMMARY OF ENERGY COSTS OF VARIOUS CROP PRODUCTION OPERATIONS

Energy Inputs Per Hectare		ERD(FF)[1] MJ	ERD(T)[2] MJ
Discing (tandem disc)			
Fuel		304.3	304.3
Machinery energy depreciation		180.6	190.2
	Total	484.9	494.5
Cultivating (spring tine)			
Fuel		202.7	202.7
Machinery energy depreciation		138.3	145.6
	Total	341.0	348.3
Harrowing (spike-tooth)			
Fuel		50.8	50.8
Machinery energy depreciation		76.9	81.0
	Total	127.7	131.8
Herbicide			
a) Material: 2,4-D amine (50% active ingredient)		42.5	46.1
b) Application: fuel		50.8	50.8
machinery energy depreciation		16.9	17.5
	Total	110.2	114.4

[1] Energy Resource Depletion (Fossil Fuel)

[2] Energy Resource Depletion (Total)

Source: Southwell, P.H. and T.M. Rothwell, *Report on Analysis of Output/Input Energy Rates of Food Production in Ontario,* School of Engineering, University of Guelph, 1977

While this has been only a cursory examination of the energy effect of non-availability of 2,4-D, it is clear that energy requirements on farms would increase. The magnitude of the increase would depend upon what changes in farming practices would take place if 2,4-D were no longer available.

Other Effects

A 2,4-D cancellation would affect Canada's balance of payments. Should Canada act alone, the effect would be negative. The effect would stem from reduced grain production accompanied by reduced export earnings on grain, as well as the increased costs of importing more expensive herbicides. Should other countries, especially the United States, also impose restrictions on 2,4-D, the impact on the balance of payments would not be obvious, as world grain prices would rise to counteract the effect of reduced grain supplies for export.

Another consideration of a 2,4-D use prohibition is the regional one. Most 2,4-D (approximately 90%) is used in the three prairie provinces for grain production. Consequently, a 2,4-D ban would primarily affect this region of the country, with Saskatchewan being affected the most (see Table 7).

LIMITATIONS OF STUDY AND AREAS FOR FURTHER RESEARCH

Economic impact analysis requires data that are inclusive, quantifiable, and reliable. Unfortunately, very little research has been done in Canada on the economic effect of agricultural chemicals. It is only when such research is carried out that data requirements are identified, including in those areas where insufficient data exist. The data requirements that have been identified as a result of this study are discussed here in order to point out constraints on the study due to the nature of the data, as well as in the hope that the knowledge will prompt future researchers to fill in some of the information gaps. While the data constraints encountered relate to this study, they would probably be similar to those in studies of other herbicides and agricultural chemicals.

Pesticide impact studies require extensive information on pesticide use. Data are required on total sales of individual pesticides. Since many pesticides can be used for various crops or purposes, data on the level of usage for each purpose are also required. Such data are limited, especially at the national level. The cancellation by Statistics Canada of the survey of pesticide sales in Canada has left a gap in this area, for the years since 1977.

The most serious data limitation is the estimate of product yield and quality response for various pest-control practices. Furthermore, available data in this area are not based on research, which takes a pesticide's productivity into account but stem from experiments such as those designed to test the efficacy of a herbicide in controlling weeds. Pesticide productivity and pesticide efficacy are related but quite different concepts. "Efficacy" refers to the pesticide's effectiveness at reducing a pest population, whereas "productivity" refers to the pesticide's effectiveness at providing more or better food and fiber, improved surroundings, etc. Thus, a highly efficacious pesticide would be relatively unproductive if its target species (e.g., weeds susceptible to 2,4-D) had little effect on crop yield or quality.

Given that most herbicides and other control techniques fail to control the entire range of weeds, the repeated and long-term use of a single herbicide or control strategy can be expected to lead to ecological shifts in weed vegetation. Long-term data on the effects of using a particular herbicide or substitute herbicides or practices are limited. Consequently, any estimate of the yield effects of a particular pesticide (such as, in this study, of 2,4-D) can be considered to be valid for only a short period, possibly no more than three years. Furthermore, it should be recognized that the useful or economic life of a chemical pesticide is limited. The economic decision to discontinue using a pesticide may be due to a loss in absolute or relative efficacy or both. A U.S. study estimated that the average economic lives of pesticides are about 10 years. [47] While it is clear that the economic life of 2,4-D is greater than 10 years, its economic usefulness will not continue indefinitely. The length of its useful period will determine the total long-term benefits of a pesticide.

The data limitations and the methodology used in this study reduce the usefulness of the results in making decisions about regulatory action. The results of this study are for a given year, while decision makers require estimates of the effect of use restriction actions for many years. Such estimates can be generated only through improved data and an economic model that predicts the major effects of a particular regulatory action.

As is noted in this study, yield improvements resulting from the use of a herbicide (such as 2,4-D) depend on what other inputs, such as other herbicides or fertilizers, are also used. The separate effects of these factors are unlikely to be additive. Little data appear to be available on the additive contributions of these factors. Furthermore, it is not clear how important each factor is in increasing average grain yield. Data on this would be useful, not only for impact analyses, but also to aid farmers in determining the cost-effectiveness of the inputs.

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[47] National Research Council, *Regulating Pesticides,* 1980, National Academy of Sciences, Washington, D.C.

Research on pesticides is, by and large, carried out on test plots at experimental stations. This permits control of variables for reliable results of the factor being tested. However, for the purposes of impact analysis such data are less than ideal. The fertility of the soil, variety and degree of weed infestations, weather conditions and other factors may not be representative of those found on operating farms. Thus studies done at experimental stations may not be representative of the average pesticide yield effects that would be observed on farms. More appropriate data for impact analysis would be obtained from tests carried out on farms over a wide region. Moreover, tests would have to be carried out over several years to take into account variations in weather and other factors.

This study also pointed out that data on effects of weeds such as level of dockage, harvesting costs, grain quality, etc. are limited. Clearly, the opportunity exists for economists to work on the use of research results in order to develop meaningful guidelines to aid agricultural scientists in their planning of research projects.

SUMMARY AND CONCLUSIONS

This study has shown that since commercial use of 2,4-D in agriculture began in 1947, it rapidly became an important aid in production. Even now 2,4-D usage remains fairly constant despite the introduction of many new herbicides. 2,4-D's major use has been and continues to be the control of broad-leaved weeds in cereal grain production in the prairie region. Lesser quantities of 2,4-D are used in eastern Canadian grain production, for brush control, and in turf management. Approximately one-half of all the seeded grain area in western Canada is treated with 2,4-D. Approximately three-quarters of all the cereal area in western Canada is treated with the two phenoxy herbicides, 2,4-D, and MCPA.

Spraying with 2,4-D increased small grain production in 1979 by 1.3 Mt with a gross value of $214 million, or a net value of $176 million, when herbicide and application costs are deducted. This net value represents 6.0% of the value of farm receipts for wheat, barley, and oats in 1979, or an additional output value of approximately $1,300 for each grain-growing farm. These results are based on an estimated 10% yield decrease resulting from not using 2,4-D on crop area treated in 1979 or any replacement herbicide. Given the uncertainty in estimating the yield effects from using 2,4-D, it should be recognized that the increase in small grain production could range from 0.7 to 2.6 Mt with a gross value ranging from $107 million to $428 million. Furthermore, 2,4-D use contributes an additional $4 million in value to the quality of wheat and reduces farm energy requirements through the reduced cultivation required.

The study shows that the benefits of 2,4-D use accrue to the producer primarily in terms of yield increases. It also shows that, if use of 2,4-D and other phenoxy herbicides were prohibited, increased costs to the farmer in terms of using more expensive, less effective herbicides and reduced crop yields could be at least $66 million and potentially much higher. The prohibition would increase farmers' total expenditures for pesticides in 1979 by at least 18.6%. The feasibility of the farmer passing these costs on to the consumer would depend, in large part, on whether other grain-producing countries similarly prohibited 2,4-D use. If Canada took unilateral action, farmers would pay most of these costs, but if the United States also prohibited 2,4-D, world grain prices would increase and result in the burden of the additional costs being borne by consumers.

It should be kept in mind that these results are subject to the limitations of the available data. Furthermore, the analysis should be viewed as applicable only to the short run (one to three years) as lack of data prevented longer-term estimation.

The aim of this study has been to assess the economic benefits of 2,4-D to agriculture and to estimate the short-term additional costs if restrictions on its use were imposed. Should concerns about pesticide safety lead to consideration of restrictions of their use, studies such as this one will enable decision makers to weigh the benefits of the pesticide against the risks. This study has shown that the economic benefits of 2,4-D to agriculture are substantial, and it is against these benefits that actual or potential risks must be assessed.

APPENDIX

Estimation of the Contribution to Wheat Yields in the Prairie Provinces from the Introduction of 2,4-D

Average yields of grain in Canada began to increase significantly only after 1950,[1] about the same time that 2,4-D was introduced. Whether this event was coincidental or whether 2,4-D had an impact on this increase will be examined here. The contributions of the various factors on grain yield will be estimated separately with the residual being attributed to 2,4-D use. This procedure circumvents the problem of extrapolating 2,4-D test plot data to all of the grain growing areas and thus provides an alternative estimating procedure. Wheat in the prairies was chosen for this study because the greater availability of data for this grain and region and also because the majority of 2,4-D is used on wheat in the prairies.

Method

Two 10-year periods, 1938-47 and 1950-59, were chosen. They represent periods just before and after the introduction of 2,4-D to the prairies. The year 1938 represents the period subsequent to the unfavorable weather conditions of the 1930s. While some 2,4-D was used in 1947, the acreage to which it was applied represented only approximately 1% of acreage planted to cereals in the prairie provinces. [2] The years 1948 and 1949 were omitted as they represent transition years when 2,4-D usage grew.

The average wheat yield in the prairies for the period from 1938 to 1947 was 1136 kg/ha while for 1950-59 it was 1358 kg/ha, [3] which represents an average yield increase of 19.5%. It may be noted that 1136 kg/ha average yield for the period 1938-47 is the same as the average yield for the 1910-29 period.

Seven identified factors that may contribute to a change in yield were considered separately in order to determine each factor's individual effect. There is a risk involved in doing this as the contribution of individual factors may not be strictly additive. Synergistic or antagonistic effects may increase or reduce the combined effects of the various factors. For this study, the possibility of such effects is ignored.

Results and Discussion

Effect of Systematic Changes in Weather Conditions

In studying trends in crop yields, it is often assumed that the effects of weather average out over time. However, Robertson [4] found in a study of the period 1923 to 1972 at Swift Current, Saskatchewan that weather underwent subtle changes during this period, and that these changes in weather conditions accounted for 73% of the yield variability of wheat.

A problem with the study was that the wheat yield data it used were based on the application of the best production techniques available at the time, which included new wheat varieties and fertilizer use. Consequently, the effects of these technological factors are imbeded in the data.

In a study of the effects of precipitation and evapotranspiration on wheat yields for the 1952-67 period, Williams [5] found that for Saskatchewan much of the variability of wheat yields can be attributed to these factors. For the more humid province, Manitoba, the yield variation is smaller and less of the variation was explained by the two factors considered.

Freyman *et al* [6] found in a study at Lethbridge, Alberta that there were no climatic changes during the 1914-80 period, and they concluded that the climate did not play a part in wheat yield increase.

While there is evidence to suggest that weather improvements have served to increase wheat yields over the period of study, Robertson's figure does not appear to apply across the prairies. Consequently, for this study I will assume that 30% of the increase is due to weather changes. On this assumption, 5.9% of the 19.5% increase in yield can be attributed to weather changes, leaving the remainder to be explained by other factors.

Effect of Changes in Crop Rotation and Summerfallow Use

Changes in the proportion of grain sown on summerfallow can affect the overall yield figures. Statistics Canada figures for the 1958-63 period indicate that

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[1] See Table 9.

[2] Manitoba Department of Agriculture, "Herbicides Used Agriculturally in Western Canada for the Control of Weeds"

[3] Statistics Canada, *Handbook of Agricultural Statistics Part I – Field Crops,* Catalog No. 21-516

[4] Robertson, Geo. W., "Wheat Yields for 50 Years at Swift Current, Saskatchewan in Relation to Weather," *Canadian Journal of Plant Science,* 54 (1974): 625-650

[5] Williams, G.D.V., "Estimates of Prairie Provincial Wheat Yields Based on Precipitation and Potential Evapotranspiration," *Canadian Journal of Plant Science,* 53 (1973), 17-30

[6] Freyman, S., C.J. Palmer, E.H. Hobbs, J.F. Dormarr, G.B. Schaalije, and J.R. Moyer, Yield Trends on Long-term Dryland Wheat Rotations at Lethbridge," *Canadian Journal of Plant Science,* 61 (1981), 609-619

wheat yields averaged 484 kg/ha more when sown on summerfallow land than on stubble. [7] Comparing the 1938-47 period to the 1950-59 period, area sown to the principal grains increased from an average of 11 470 000 ha to an average of 12 893 000 ha. [8] During this period, summerfallow acreage increased from an average of 8 300 000 to 9 685 000 ha. Thus, the proportion of summerfallow land to land seeded to these crops increased slightly, from 72.4% to 75.3% (a 2.9-point increase). Assuming that the 484 kg/ha increase applied to the previous period, average yield would have increased by 2.9% times 484 kg or 14 kg. This represents an increase in the average yield of 1.1%.

Effect of Fertilizer Use and Soil Fertility

For the two periods considered, fertilizer use on the prairies increase from an average of 16 300 t to an average of 75 300 t. [9] Assuming a fertilization rate of 46 kg/ha [10] this represents 0.9 Mha and 1.6 Mha fertilized, respectively. Assuming that most fertilizer use was that on wheat and barley, this represents 2.9% and 12.2% of seeded area, respectively.

Based on an estimated increase in yield of 10 kg wheat/1 kg of fertilizer, [11] the expected yield increase would be 460 kg/ha on the fertilized land. Counteracting this increase in yield on the fertilized crop would be a decrease in yield in the remaining 88% crop area due to declining soil fertility. Soil experts estimate that it was not until 1967 that fertilizer use had any significant effect on overall yield. [12] Consequently, for the periods considered, I will assume that increases in yields due to fertilizer application are just offset by the decline in yield on the remaining crop area due to fertility declines.

Effect of Insect Control

The two main insect pests in wheat have been the sawfly and grasshopper. Data are available that estimate crop losses attributable to these pests of Saskatchewan. [13] For the 1938-47 period, the average estimated losses in wheat due to sawfly damage were 6.3% while that due to grasshoppers was 4.0%. The corresponding averages for the 1950-58 period were 3.4% and 0.9%. Thus, during the latter period, there was a net reduction of grain yield losses of 6% attributable to insect pests. Sawfly control was achieved through the introduction of sawfly resistant varieties of wheat, while grasshopper control was mainly due to insecticide use. For this study it will be assumed that a 6% yield increase due to insect control for the 1950-59 period applied to all of the prairie region.

Effects of Wheat Variety Changes and Wheat Diseases

While new varieties were introduced during the periods discussed, the bulk of the wheat sown on the prairie provinces was Thatcher, a variety introduced in 1935. [14] A severe infestation of stem rust in 1954 substantially decreased wheat yields and led to the decreasing popularity of Thatcher after that point, as Selkirk, a more rust resistant variety, was introduced that year. Yield data indicate little overall difference in the yield potential of Selkirk over that of Thatcher. [15]

Peturson [16] noted that during the 1939-51 period no wheat yield losses due to stem rust were experienced. For the years 1953, 1954, and 1955, he estimated that yield losses in wheat due to stem and leaf rust were 6.9%, 33%, and 1.8%. This amounts to an average yield loss due to rust of 4.2% during the 1950-59 period. Another heavy rust year was 1938, for which no estimate of yield loss is available, but it was observed to have had a heavier rust infestation than in 1935 [17] when it was estimated that yields in wheat were reduced by 25%. [18] For this study, I assume the 1938 loss to have been 32% for a 1938-47 average of

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7 Statistics Canada, *Summer-fallow and Stubble Acreage and Yield of Specific Crops – Prairie Provinces,* Catalog No. 22-002

8 Statistics Canada, *Handbook of Agricultural Statistics, Part I, Field Crops,* Catalog No. 21-516

9 Statistics Canada, *Fertilizer Trade*

10 Thomas, A. Gordon, Manitoba Weed Survey Questionnaire Data, 1978 and 1979, Agriculture Canada

11 Ridley, A.O. and R.A. Hedlin, "Crop Yields and Soil Management on the Canadian Prairies, Past and Present," *Canadian Journal of Soil Science,* 60 (1980): 393-402

12 Hannah, A.E., "Production Possibilities for Grain in Western Canada," *Canadian Journal of Agricultural Economics,* 16 (1968): 71-76

13 *Annual Report of the Department of Agriculture of the Province of Saskatchewan,* various years

14 Graham, J.E. and W.L. Porteous, "Study of Long Term Trends and Annual Variations in Wheat Yields in the Prairie Provinces," 1963, unpublished paper

15 Hedlin, R.A. and L.R. Rigaux, "Crop Yield Changes in the Prairie Provinces 1958-1976," *Annual Conference of Manitoba Agronomists, Technical and Scientific Papers,* 1976

16 Peturson, B., "Wheat Rust Epidemics in Western Canada in 1953, 1954 and 1955", *Canadian Journal of Plant Science,* 38 (1958): 16-28

17 Craigie, J.H., "Epidemiology of Stem Rust in Western Canada," *Scientific Agriculture,* 25 (1936): 285-401

18 Greany, F.J., "Cereal Rust Losses in Western Canada," *Scientific Agriculture,* 16 (1936): 608-613

3.2. Thus, the net effect is a 1.0% larger yield reduction due to rust in the 1950-59 period than the earlier one.

The yield increase due to the introduction of sawfly-resistant wheat varieties was already accounted for in the previous section.

Effect of Increased Mechanization and Improved Cultural Practices

These factors are expected to have a positive effect on yields due to better timed operations and improved cultivation as well as improved methods of soil moisture preservation. The trend would likely have been gradual during the periods considered, showing noticeable effects only during the first and last years. No estimate of the effect of these factors is available. Hutcheon *et al*[19] estimate that through improvements in soil management, such as depth of seeding, time of seeding, rate of seeding, seed bed preparation, and frequency of tillage, crop yields could be increased by 30%.

For the purposes of this study, I will assume that the effects were small over the period studied, and that they contributed 2% of the observed wheat yield increase.

Herbicide

Summing up the effects of the above six factors indicates that they account for 14.0% of the observed 19.5% increase in wheat yield. This leaves 5.5% unexplained, and it is assumed here that this can be attributable to the effect of herbicide use during the 1950-59 period.

During this period, the primary herbicide used was 2,4-D, and a small amount of MCPA was also used. The area treated with 2,4-D and MCPA during the 1950-59 period was estimated to be 5.5 Mha.[20]

Assuming that 75%, or 4.1 Mha of the 5.5 Mha, were seeded to wheat, this means that 43% of the total area planted to wheat was treated with 2,4-D. Taking the assumption that the 5.5% average wheat yield increase can be attributed to herbicide use, the yield increase in the herbicide-treated area was 12.8%.

The yield increases in wheat attributable to 2,4-D use resulted not only from a reduction in competition from weeds but also from changes in cultural practices. With 2,4-D (as well as other herbicides), fewer cultivations are needed in the spring; this results in better seed bed moisture conditions. This in turn means more efficient use of available moisture and hence increased yields as moisture is usually the limiting factor to increasing grain yields in the prairies. While no direct data are available to assess this effect, data from an experiment on minimum tillage systems for summerfallow indicated that up to a 15% increase in wheat yield could result in wheat grown on fallow where weed control was primarily by chemical means, versus fallow where fallow where weed control was entirely by tillage operations.[21] This yield-increase effect was attributed to improved moisture conservation during the fallow period.

Summary and Conclusions

Based on a number of assumptions and using historial data it was estimated that 2,4-D use increased yields in wheat by approximately 13%. While the calculation represents an estimate, based on the available data, it is also based on a number of critical assumptions which may not be valid in all cases. Consequently, the value obtained should be taken as only approximate and illustrative of possible effect of 2,4-D.

This study has examined the factors which contributed to the increase in average wheat yields when comparing the 1938-47 period with that of 1950-59. It has shown that the introduction of 2,4-D may have contributed significantly to this increase.

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[19] Hutcheon, W.L., J.S. Clayton and D.A. Rennie, Saskatchewan's Land Resource, *Proceedings Saskatchewan Resources Conference,* 1964, pp. 407-422

[20] Manitoba Department of Agriculture, "Herbicides Used Agriculturally for Weed Control in Western Canada"

[21] Zentner, R.P., Rand C.W. Lindwall, "Economic Evaluation of Minimum Tillage Systems for Summer-fallow in Southern Alberta, *Canadian Journal of Plant Science,* 62 (1982): 631-638

An economic assessment of the benefits of captan use in Canada

Ed Dunnett

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Very few published data sources were available for the preparation of this report. In this connection, the author would like to thank Mr. Gus Butt of Chipman, Inc., Mr. Jack Oakley of Chevron Chemical (Canada) Ltd., and Mr. David Latter of Interprovincial Co-operative for supplying captan sales and utilization data of great importance in this report. Thanks are also due to Dr. Harry Krehm and various research scientists of Research Branch, Agriculture Canada for providing estimates of various crop losses without captan. Finally, thanks are due to Geraldine Graham of Health and Welfare Canada for data on captan residues. Full responsibility for the use of all these data, of course, remains with the author.

Captan is an important fungicide in the Canadian agricultural economy. It is extensively used as a foliar treatment to protect fruit crops from rot and other fungal diseases, especially apples in Ontario, Quebec, and the Atlantic provinces. It is also used as a seed treatment for a number of crops, notably corn, soybeans, and potatoes. It has a number of other uses as well. Its value to users is difficult to determine, mainly because of uncertainty over available and acceptable substitute fungicides for captan. A key issue then is this: without captan, how would the diseases now controlled by captan be controlled? To what extent would countries in which captan use is restricted be at a competitive disadvantage to those countries where continued use is permitted? This report only partly answers these questions. It does indicate that if captan were discontinued and not replaced by another fungicide, annual losses could be in the order of $100-$150 million [1] a year, clearly indicating the destructive potential of these fungal diseases. The degree to which such losses could be prevented depends upon the availability of alternative pesticides after all the health reviews are complete.

Besides adversely affecting Canadian agricultural production, a captan cancellation in Canada alone could also interfere with international trade. About three-quarters of the fruits and one-third of the vegetables consumed in Canada each year are imported. As some of the imports valued at over $1.5 billion in 1980 could be carrying residues of captan, trade could be disrupted, with adverse consequences for Canadian distributors and consumers.

INTRODUCTION

The purpose of this study is to examine, to the extent possible by available data, the economic value of the fungicide, captan, to Canadians, particularly to users of the product. Such a study contains important information for determining which uses of the product to permit and which to restrict. At present, captan is an important fungicide in Canada and in many other parts of the world, including Europe and the United States. In Canada, it is extensively used to control a broad spectrum of rot and other fungal diseases in many fruit crops, especially apples in eastern regions where humid weather conditions make these diseases a special problem. It also plays a very important role as a seed treatment in protecting a number of crops, especially corn, soybeans, and potatoes. It is also used to a lesser extent on vegetable and ornamental crops, for various home and garden purposes, and as a material preservative in products like paints and wallpaper paste.

This report is divided into five parts. The introduction considers some of the important economic issues in determining the value of captan to its users and also some of the economic implications of various actions to remove captan from use. The second section describes existing use of captan worldwide and in Canada, based on data provided by manufacturers and provided by distributors of the product. The third section presents an evaluation of the benefits of captan based on Canadian use data, estimates provided by research scientists in Canada, and evaluation studies that have been carried out for the United States. The fourth section considers the issue of a residue-free food supply, and the fifth section draws conclusions.

[1] Estimate is for most agricultural and ornamental uses only. It is not for home and garden and industrial uses.

The economic value of any particular pesticide depends on the extent to which the pesticide is used, its cost, and efficacy, and the cost, efficacy, and availability of substitute pest control materials or techniques.[2] This value is at least potentially measurable in the form of lower production costs compared with those incurred by the use of alternative pesticides and in the form of a higher value of output where substitute materials deliver a lower yield or a crop of lower quality.

From this observation, it readily became apparent that benefits of a particular pesticide accrue to users of the product. In the case of a fungicide like captan, benefits to a grower occur in the form of a higher net farm income resulting from increased production of a crop of higher quality. However, benefits are not, of course, confined to users of the pesticide. They also accrue to consumers of the treated products, in the captan case, in the form of a more abundant supply of lower cost quality fresh product than would otherwise occur.

It is also apparent that the magnitude of benefits depends not only on the extent to which a pesticide is used but also on the availability of acceptable alternative pesticides. In the captan case, there is a dilemma in selecting alternative chemicals. Many of the alternatives are less effective in controlling the broad range of diseases that captan controls throughout the growing season or have adverse side effects such as being potentially damaging to plants and trees. Looking to the future, it is not clear whether the number of alternative effective chemicals will increase or diminish. While it is possible that new products will be registered for use over the next few years, it is important to recognize that the effectiveness of some existing chemicals could be affected by the development of resistant pathogens to them. To deal with the dilemma, two types of benefits are calculated in this study — one where a substitute material is used and one where no substitute chemicals are used.

Thus far, the implications of restricting captan use on domestic food production have been examined. However, certain actions, such as requiring a residue-free food supply, might not affect only domestic production but international trade as well. Captan is used not only in Canada but also abroad, notably in the United States. As can be seen in Appendix A, Canada imports significant quantities of agricultural products, including an annual expenditure of about $1.5 billion on fruits, vegetables, potatoes, and nuts, some of which have the potential to be carrying residues of captan when they enter the country. Similarly, other products such as paints treated with captan abroad and exported to Canada may contain captan. A cancellation of captan, therefore, might not only disrupt Canadian production but Canadian trade flows as well. The severity of the trade disruption could be negligible but it could also be very significant if products with the potential for residues were no longer given access to the Canadian market.

Finally, the economic effect of a ban of a particular pesticide depends not only on the issues discussed so far but also on the type of action that is taken. A sudden ban would be likely to have the greatest cost impact. A phased withdrawal announced in advance could reduce the cost impact somewhat by allowing stocks of the chemical held by the manufacturers and distributors to pass through and by allowing substitute materials, assuming they exist, to be moved into place in response to users' new needs.

CAPTAN USE WORLDWIDE AND IN CANADA

Captan is an important fungicide in Canada as well as many other parts of the world. The active ingredients of the chemical are produced at factories in Ohio, Israel and France, formulated into a wide variety of end use products, and distributed for use through many parts of the world including Europe, the United States, and Canada. Captan is also a well established chemical, having been in constant use for approximately 30 years.

According to sales data provided by distributors and formulators of captan, namely Chipman Inc., Chevron Chemical (Canada) Ltd., and Interprovincial Co-operative, the total quantity of captan sold and used in Canada approximates the figures given in Table 1.

It is readily apparent from the figures that foliar treatment of horticultural crops is by far the most extensive use. Furthermore, while captan is registered for use in a number of fruit and vegetable crops, its actual use is heavily concentrated in fruit crops, notably apples, peaches, strawberries, raspberries, and grapes. About 95% of the foliar treatment occurs in fruit crops, with the remaining 5% in vegetables. Of the captan used on fruit, about 70% is applied to apples, 10% on peaches, 10% on strawberries and 10% on grapes and other fruit crops. Regional use of captan is also quite distinct. Despite the importance of the fruit industry in British Columbia, it is estimated that only about 10% of the sales of captan used for foliar application are made in B.C., reflecting the drier climate in this region, which is less conducive to the development of rot and other fungal diseases. About 75% of all foliar applications of captan occur in Ontario and Quebec with the balance being used in the Atlantic area. Furthermore, it is estimated that 100% of the apple crop in the Atlantic area is captan treated, about 80 to

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	1976	1977	1978	1979	1980	Ave.	%
	tonnes (active ingredients only)						
Foliar treatment[2] in horticultural crops	250.3	277.1	250.3	233.7	259.7	254.2	86
Seed treatment	26.9	30.4	27.4	25.9	21.9	26.5	9
Home and garden use	12.9	14.9	10.2	14.7	16.9	13.9	5
Total	290.1	322.4	287.9	274.3	298.5	294.6	

[1] Does not include Captan formulated into seed treatment products and exported from Canada. Similarly, captan applied to products abroad such as wallpaper paste or agricultural seed and then exported to Canada is not included in any of these figures.

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90% in Quebec, and 60 to 70% in Ontario, with the balance of these crops being treated with compounds such as metiram. In western Canada, captan is used as a pre-bloom spray for apples and extensively applied in the raspberry crop.

Captan is also used on a smaller scale but it will be seen in the next section in a vitally important role as a treatment of the seeds of various crops. The most extensive use as a seed treatment occurs in corn, and to a lesser extent in soybeans. Captan is also used on a more limited scale in the home and garden environment, e.g., to protect roses and lawns and by people growing their own fruits and vegetables. It is also used on various ornamental plants such as trees and shrubs, and as a preservative in industrial products such as paints and lacquers, and products like shower curtains exposed to high humidity. No precise data have been obtained for industrial uses, but usage here is believed to be relatively small.

EVALUATION OF THE BENEFITS OF CAPTAN

As was seen in the previous section, captan is being used on a wide variety of crops. The value of these crops for 1978 is listed in Table 2.

Captan is used to provide protection against a broad spectrum of diseases. In fruit, it provides protection against some of the major disease threats in Canada such as scab in apples and pears, brown rot in stone fruit like peaches and nectarines, and botrytis fruit rot in small fruits like strawberries and raspberries. It also provides effective protection against a variety of seed and seedling diseases. Fungal disease is a threat throughout Canada at any time, but without control, the incidence of disease and losses from infected fruit would increase significantly during humid weather.

Growers' choice of captan reflects a number of important considerations. In apples, for example, cap-

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Captan is also used on a smaller scale but it will be seen in the next section in a vitally important role as a treatment of the seeds of various crops. The most extensive use as a seed treatment occurs in corn, and to a lesser extent in soybeans. Captan is also used on a more limited scale in the home and garden environment, e.g., to protect roses and lawns and by people growing their own fruits and vegetables. It is also used on various ornamental plants such as trees and shrubs, and as a preservative in industrial products such as paints and lacquers, and products like shower curtains exposed to high humidity. No precise data have been obtained for industrial uses, but usage here is believed to be relatively small.

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tan provides effective protection not only against apple scab but also a variety of other diseases such as bitter rot, black rot, bull's-eye rot, and sooty blotch. Among its other advantages are that it can be applied in some uses to within one day of harvest, it has a low phytotoxicity, it is compatible with other compounds, and in 30 years of use, the development of strains resistant to captan have never been observed. Without captan, the effectiveness of other fungicides such as benomyl and thiophanate-methyl would be expected to fall as these chemicals are frequently used in a spray program that includes captan to prevent a buildup of resistant pathogens.

While there are a number of alternative registered fruit and vegetable fungicides, few of them can match the overall performance of captan. Some are effective only against specific diseases, others are not effective against resistant pathogens, and others have serious adverse side effects such as being potentially damaging, either to fruit trees and plants or to beneficial insects in integrated pest management programs. In short, captan adds significantly to the industry's capability to protect against disease.

But the question remains just how important captan is to users in Canada. It should be stated at the outset that a precise answer to this question cannot be given as both the knowledge and data required to say precisely what would happen without captan are lacking. Nevertheless, the captan utilization data and other evaluation studies that have been prepared can be used to give a broad indication of its value.

In November 1980, the Chevron Chemical Company of Richmond, California presented a report [3] to the U.S. Environmental Protection Agency (EPA) evaluating the importance of captan in the United States. The company estimated that captan was worth approximately $500 million to U.S. users in 1978. [4]

In September 1980, a study [5] prepared by the EPA looked at the benefits of a larger group of fungicide compounds and derived an estimate for these. This study considered the value of all fungicides under review at the time (RPAR, PRE-RPAR, or PRE-RPAR referral), including maneb and mancozeb, captan, chlorothalonil, captafol, benomyl, folpet, thiram, PCNB, zineb, nabam, metiram. This group of chemicals had an estimated annual value of $5.7 billion to its users. The ten-fold difference in estimates between the two studies serves to illustrate the importance of the broader group of fungicides to users in controlling disease. The losses in both these studies occurred chiefly in reduced value of output whenever use of the compound or compounds was cancelled because of the effects of various crop diseases.

Some explanation of the Chevron figure is required so that the meaning of this number is clearly understood. About 90% of the benefits identified in the Chevron study accrued to fruit growers, almond producers, and growers who use captan-treated seed. In these cases, the value of captan-treated output was compared with the value of output without fungicide treatment. For average weather conditions, this in some sense represents the maximum value of current captan use as growers could reduce their losses to some extent in the event of a captan cancellation by applying a substitute fungicide. However, it should also be emphasized that the Chevron study considered only the value of actual use in 1978 and did not consider its potential use and value in the event that the use of other fungicide material were cancelled. Such an evaluation is, of course, possible only as part of an evaluation of all fungicide material. Both of these factors need to be taken into account in interpreting the numerical estimate presented in the report.

Applying the methodology used in the Chevron study to Canadian utilization data gives the following results. Farm cash receipts from apple production in Canada in 1978 are estimated at $93.5 million. $33.1 million in receipts accrued in British Columbia where there is very limited captan use except as a pre-bloom spray. [6] It is estimated on the basis of the data supplied by the captan distributors, that approximately $47 million of apples are directly dependent upon captan treatment in eastern Canada. If no fungicide were applied on these crops, it is likely (based on American estimates) that the presence of diseases such as apple scab would divert infected apples from the fresh to the processing market, bringing about a 40% decline in the value of the crop. [7] This implies a dollar loss of $19 million a year to apple growers. Captan utilization data for other fruit crops and for vegetables is too limited to permit a similar calculation for any other horticultural product. However, these losses have been estimated by research scientists in the various research stations across Canada and these estimates are presented in Table 3.

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[3] *Evaluation of the Benefits of the Fungicide Captan.*

[4] In a similar submission entitled "Response of the Stauffer Chemical Company to the Notice of Rebuttable Presumption against registration and continued registration of pesticide products containing captan", Stauffer estimated the annual value of Captan to users in excess of $2 billion (p. 125).

[5] *Fungicides: An Overview of Their Significance to Agriculture.*

[6] In the East, Captan is often applied repeatedly throughout the growing season.

[7] *Evaluation of Benefits of Fungicide Captan,* Chevron Chemical Company, p. V-11.

TABLE 3. IMPUTED LOSSES FROM NOT REPLACING CAPTAN

Crop	Farm Cash Receipts Canada 1978[1]	Expected Loss from Using No Chemical to Replace Captan
	$ million	$ million
Grapes	24.8	7.4
Peaches	17.3	3.5
Raspberries	14.2	2.5 – 5.0
Blueberries	17.5	2.5
Strawberries	23.5	4.7 – 18.8[2]
Cherries	9.5	2.0
Potatoes	178.7	11.0
Beets	2.4	0.5
Celery	5.9	0.1
Total	293.8	34.2 – 50.8

[1] Data for pears, nectarines, apricots, and plums were not available.

[2] Losses depend significantly on weather conditions during growing season.

An alternative way of measuring the value of captan is to consider the additional cost of using substitute materials. The most likely substitute to protect the apple crop is metiram. According to price list data prepared by distributors, the suggested retail price for captan (in 1980) was $7.72/kg of captan 80% Wettable Powder (WP). The suggested retail price for metiram (polyram) was $5.56/kg of polyram 80% Wettable Powder (WP). According to use patterns, determined by Pesticides Division of Agriculture Canada, to protect against apple scab, captan 80% WP should be used at a rate of 1 kg active ingredients per 1 kL of water, while polyram 80% WP should be used at a rate of 1.6 kg active ingredients per 1 kL of water. This places the per-hectare cost of metiram at about 15% above the cost of captan. When it is considered that approximately two-thirds of the captan used for foliar treatment of horticultural crops was applied to apples, total cost of captan to treat apples in 1980 was approximately $1.7 million. [8] Using metiram as a substitute would cost approximately $255 000 extra. While the previous method derived the maximum value of captan utilization in apples, it should be clearly understood that this calculation represents the minimum value of this use of captan. Its value could rise considerably above the minimum figure, if sufficient quantities of substitute material were not available to growers to meet their new needs in the event of a captan cancellation. Secondly, the cost of metiram and others could increase in response to higher demand. Moreover, no attempt has been made in this example to compare the effectiveness of captan with that of metiram as detailed data are not available.

[8] Cost of captan per kg active ingredients is $9.92; 173 t applied on apples.

Captan also plays a very important role in protecting a number of crops from seed and seedling diseases and rots when applied as a seed treatment. It also serves to buffer the phytotoxic effects of insecticide components of seed treatment materials.

Captan's most important use is as a corn seed treatment. According to data published by the Ontario Ministry of Agriculture and Food, [9] corn seed treated with captan was planted on approximately 611 000 ha of land. This represents approximately 60% of the total area of corn for grain and for fodder in Ontario.

Seed treatment in corn is extremely important to ensure that the corn crop come up. The Chevron study [10] estimated that if seed were not treated, seeding would have to be delayed, with a consequent 10% crop yield reduction, and that seedling diseases would reduce yield by a further 10%. Using this information and assuming that 60% of the corn for grain and for fodder is captan-treated across Canada, estimated losses for corn sold for grain and not treated with captan are approximately $24 million for 1978. This calculation assumes that no alternative fungicides were used, and therefore represents the maximum value to users. In the event of a captan cancellation, growers could reduce their losses by using seed treated with alternative materials. A number of other materials are registered for corn seed treatment but the only material broadly considered as efficacious as captan is thiram.

[9] Survey of Pesticide Use In Ontario, 1978. Economics Branch, Ontario Ministry of Agriculture and Food.

[10] *Evaluation of the Benefits of the Fungicide Captan,* p. V-35.

Captan is also used as a seed treatment in a number of other crops, notably rapeseeds, soybeans, potatoes, and dry beans. Furthermore, while captan use may not be extensive, its *potential* value to rapeseed and soybean growers needs to be recognized in the event that thiram use is discontinued. Thiram is the only registered alternative to captan to control a number of seed and seedling diseases in these commodities. In 1978, rapeseed was Canada's second most important cash crop. In these areas, data are too limited to permit a calculation of captan value to users.

Captan has a number of other uses besides those discussed in this section. It is registered to protect ornamental crops; this was worth $153.6 million in 1978. Research scientists estimate losses of $30 to $60 million if captan were withdrawn and not replaced by some other treatment. Captan is also used in the greenhouse tobacco industry; estimates of its value in this use are not available. Captan is also registered as a preservative for vinyl, paint, lacquer, wallpaper, paste, rubber, and polyethylene and as an ingredient for powdered hand soap. Generally, usage in these areas is more restricted. Data are not sufficiently detailed to permit an evaluation of all uses of captan.

In sum, captan is a versatile, highly effective product that provides protection against fungi for a wide variety of users. If no substitute materials were used in place of existing captan applications, economic losses to agricultural users are estimated to be in the order of $100 to $150 million per year. [11] These losses could be reduced by using some alternative chemical.

IMPLICATIONS OF REQUIRING A FOOD SUPPLY FREE OF CAPTAN RESIDUES

So far, I have presented benefit data. These provide information about the possible implications for Canadian production if the use captan in Canada were no longer permitted. An important question is what would happen if captan use were restricted in Canada without such restrictions applying abroad? It is particularly important to assess the economic consequences of requiring that all food sold at the retail level in Canada be free of any captan residues. Such a requirement might affect not only domestic production but international trade in food products as well.

Under existing law in both the United States and Canada, various food products are permitted to contain minute traces of captan after they leave the farm gate. For Canada, these tolerances are five parts captan per million parts of commodity (ppm) and apply at the consumer level. In the U.S. the tolerances vary from 2 to 100 parts per million and apply at the farm gate level. These tolerances are developed to enable growers to protect their crops at a time when their produce is at its greatest value and when disease is still a threat — before harvest and, in some cases, post-harvest.

The important issue here is to what extent are these tolerances used, i.e., to what extent do any captan residues persist and appear at the retail level? If any such residues did appear, both domestic production and international trade in food products could be affected by a requirement for a captan-free food supply.

Implications for Domestic Production

In Canada, monitoring of captan residues in the food supply at various stages of production and marketing is conducted by Health and Welfare Canada. Data from two projects of domestic fruits and vegetables revealed that captan residues were present in a basket of items. These items were sampled and examined from various parts of the food system, including the retail sector. One project [12] based on a random sampling procedure indicated that about 7% of 395 specimens contained captan residues of more than the detection limit of 0.1 ppm. Furthermore, the incidence of residues was highest among strawberries and peaches. In another project [13] where sampling is biased because of the practice of taking follow-up specimens where any problems may have been encountered, 8% of the 759 specimens of fruits and vegetables had captan residues greater than 0.1 ppm. In this case the incidence was highest for strawberries and raspberries. It should be noted that in all cases, detected residues were below maximum levels established by law.

The implications of these findings are that growers would most likely have to alter their captan use patterns to comply with a residue-free food supply requirement (less than 0.1 ppm). The economic consequences could be especially serious for small-fruit producers such as strawberries where disease protection is needed right up to harvest and for stone fruit producers who must often use captan through harvest to protect against diseases such as brown rot.

Implications for International Trade

A requirement for a food supply free from captan residue might not affect only Canadian production but international trade as well. In 1980, Canadians imported about $1.5 billion of fruits, vegetables, and nuts. Data from the Health and Welfare monitoring and compliance projects mentioned in connection with domestic production indicate that some of the

[11] Benefits of some uses were not calculated and not estimated in this figure.

[12] Project FM 18, Health Protection Branch, Health and Welfare Canada, 1978/79. Monitoring Project.

[13] Project FBAO, Health Protection Branch, Health and Welfare Canada, 1978/81. Compliance Project.

imports as well as domestic products are likely carrying small traces of captan. One project [14] using random sampling indicated about 6% of 215 imported fruit and vegetable specimens contained captan residues greater than 0.1 ppm. Another project [15] using follow-up sampling procedures found about 3% of 641 observed specimen contained detectable traces of captan greater than 0.1 ppm. In these cases, the incidence of residues was highest in strawberries and in grapes.

The important implication of these findings is that the requirement of a residue-free food supply could disrupt a significant part of Canada's international trade. The significance of the disruption would obviously depend critically upon the precise action chosen to keep the food supply free of residues. The severity of the trade disruption could be quite negligible but it could also be very significant if products with the potential for residues were no longer given access to the Canadian market. Any action of the latter type could indeed lead to higher fresh produce prices for consumers or physical shortages of products or both.

In terms of international trade arrangements, under the terms and conditions of the General Agreement on Tariffs and Trade (GATT), it would be possible for Canada to restrict trade provided it could demonstrate to its trading partners that such a restriction is clearly to protect health and safety and not an economic restriction.

Canada's imports in food products related to the captan issue are detailed in Appendix A. Imports of other non-food products that could be carrying some captan are detailed in Appendix D. These include various agricultural seeds for sowing and some industrial products such as wallpaper and shower curtains as well.

CONCLUSION

The purpose of this study is to assess the economic value of captan to users of the fungicide in Canada. As indicated in the previous section, data are too limited to present a detailed evaluation of all uses of captan. Nevertheless, from the data and the analysis it is possible to draw three broad conclusions.

First, the economic value to users of any particular fungicide compound depends crucially on the extent to which the compound is used and on the quality of alternative disease-control techniques. What this means is that the economic importance of a particular compound could rise sharply if the effectiveness of some alternative materials were suddenly reduced by the development of resistant diseases or if other effective materials were removed from the market for health and safety reasons. This has important implications for situations where a number of disease-controlling chemicals are being reviewed over a period. Ideally, a disease-control strategy is worked out after all the health reviews are complete. If this is not possible, it is important to point out that the materials reviewed first could be underestimated in value because of the apparent availability at this stage of a number of alternative disease-control materials. This study has shown that when substitute materials are not applied, substantial economic losses would be involved if captan use were discontinued.

Second, application of fungicides like captan are extremely important, particularly to fruit, vegetable, and corn growers in eastern Canada. Without captan and other materials, growers in humid regions such as eastern Canada could be placed at a significant competitive disadvantage compared with growers in drier climates and with growers in other areas where use of these chemicals is permitted. The result would most likely be a smaller fruit and vegetable industry in Canada, particularly in the eastern regions.

For the Canadian consumer, losses from a captan cancellation may occur not only because of reduced Canadian production. In 1978, Canadians imported over $1 billion of fruits, vegetables, and nuts, mainly from the United States. Some of these, such as apples, grapes, and strawberries are treated with captan and have been shown in test samples to carry captan residues when they crossed the border into Canada. If this flow of captan-treated production were stopped, there could be shortages or higher prices, particularly in the Canadian off-season.

[14] Project FM 18

[15] Project FBAO

APPENDIX A

PRINCIPAL IMPORTS OF FRUITS AND VEGETABLES TOTAL IMPORTS AND IMPORTS FROM UNITED STATES 1978

	Total	From U.S.		Total	From U.S.
			– $ millions –		
Fruits and nuts	818.3	–	Vegetables and potatoes	439.1	–
Orange juice concentrates	96.5	46.5	Lettuce	59.4	59.3
Fresh oranges	88.0	68.5	Fresh tomatoes	56.1	43.1
Fresh grapes	81.4	68.0	Canned mushrooms	28.3	0.3
Fresh bananas	74.7	0.0	Celery	26.1	26.1
Fresh apples	39.4	31.1	Table potatoes	25.9	25.9

Source: *Canada's Trade in Agricultural Products*, Agriculture Canada

PRINCIPAL IMPORTS OF FRUITS AND VEGETABLES TOTAL IMPORTS AND IMPORTS FROM UNITED STATES 1980

	Total	From U.S.		Total	From U.S.
			– $ millions –		
Fruits and nuts	1 008.3	648.0	Vegetables and potatoes	497.4	382.5
Orange juice concentrates	108.3	68.0	Lettuce	56.8	56.7
Fresh oranges	100.6	75.4	Fresh tomatoes	71.5	62.7
Fresh grapes	108.2	89.7	Canned mushrooms	34.7	0.04
Fresh bananas	98.5	0.3	Celery	25.4	25.4
Fresh apples	46.5	34.0	Table potatoes	23.7	23.7

Source: *Canada's Trade in Agricultural Products*, Agriculture Canada

APPENDIX B

ESTIMATED CAPTAN USE IN THE U.S. IN 1979

Site Used	Percent of Total Usage	Quantity of active ingredients applied	Percent of Crop or Site Treated
	(%)	(tonnes)	(%)
Pome fruits	22.9		
Apples		1123 – 1143	31.7 – 32.3
Pears		9 – 23	1.9 – 5.5
Stone fruits	8.7		
Cherries		26 – 70	5.1 – 13.8
Peaches, nectarines, apricots		298 – 343	18.2 – 21.0
Plums, prunes		27	6.7
Small fruits	13.0		
Stawberries		46 – 117	70.0 – 90.0
Grapes		282 – 294	29.6 – 30.9
Brambles		60	90.0
Blueberries		191	90.0
Other fruits	12.7		
Almonds		589	85.0
Citrus		57	7.0

(continued)

APPENDIX B

ESTIMATED CAPTAN USE IN THE U.S. IN 1979 (Concluded)

Site Used	Percent of Total Usage	Quantity of active ingredients applied	Percent of Crop or Site Treated
	(%)	(tonnes)	(%)
Field crops	19.5		
Corn, dent and sweet		505	100.0
Small grains and other field crops including peanuts		313 – 329	–
Cotton		155 – 156	80.0
Potatoes (seed treated)	9.9	366 – 503	48.3 – 66.4
Vegetables (foliar or seed)	3.6	159 – 181	–
Homeowner	8.9	454	–
Ornamental	0.4	20 – 23	–
Turf		9	–
Forest and other crops		3	–
(Tropical fruit and vegetables)		5	–
Total	100.0		

Source: US DA/State/EPA Captan Assessment Team Draft Report, *An Analysis of Current Captan Uses; Their Benefits, the Role of Alternatives, Impact to Agriculture from Changes in Captan Use Patterns and Applicator Exposure.* January 1982

APPENDIX C

QUANTITIES OF MAJOR FUNGICIDES USED IN ONTARIO, 1978

On All Fruit		On All Vegetables	
	tonnes (active ingredients)		
Mancozeb and Dinocap	59.3	Metiram	43.0
Captan	54.3	Captafol	35.9
Metiram	39.3	Chlorothalonil	32.5
		Captan	0.1
Total (all fungicides)	187.9	Total (all fungicides)	184.3

Source: *Survey of Pesticide Use In Ontario,* 1978, Economics Branch, Ontario Ministry of Agriculture and Food

APPENDIX D

INDUSTRIAL IMPORTS THAT MAY CONTAIN CAPTAN TOTAL IMPORTS AND IMPORTS FROM UNITED STATES

	1978		1980	
	Total	From U.S.	Total	From U.S.
	– $ millions –			
Wallpaper	23.0	12.4	20.0	11.4
Paint	41.6	40.0	50.1	47.8
Laquereed	5.7	5.6	4.9	4.7
Vinyl products	171.5	150.8	174.7	152.9
Polyethylene	83.4	76.4	84.3	84.0
Rubber products (e.g., final products exposed to high humidity)	363.7	219.3	477.3	294.6
Totals	688.9	504.5	811.3	595.4

Source: Statistics Canada, *Imports by Commodities,* Catalog No. 65-007

SEED IMPORTS THAT MAY CONTAIN CAPTAN
TOTAL IMPORTS AND IMPORTS FROM UNITED STATES

	1978		1980	
	Total	From U.S.	Total	From U.S.
	– $ millions –			
Alfalfa seed	7.7	7.5	10.2	10.2
Bean seed	2.9	2.8	3.6	3.5
Corn seed	8.2	8.2	12.8	12.7
Grass seed	9.6	8.9	10.3	10.0
Pea seed	2.6	2.5	3.2	3.1
Totals	31.0	31.0	40.1	40.1

Source: *Canada's Trade in Agricultural Products*, Agriculture Canada

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J.P. Connell, Deputy Minister

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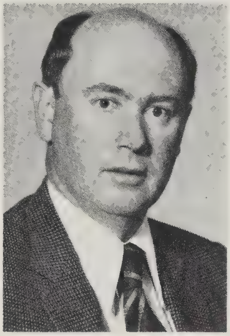

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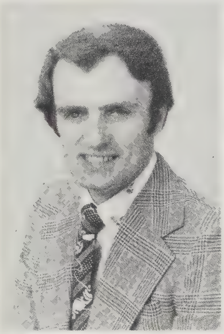

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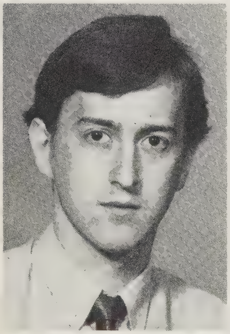

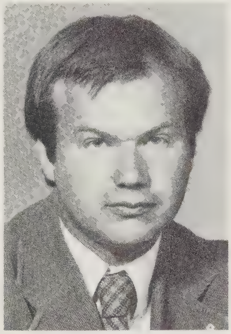

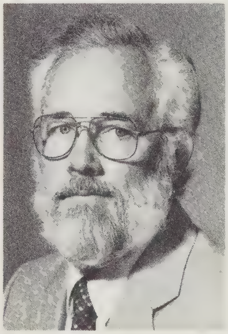

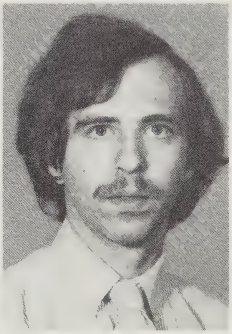

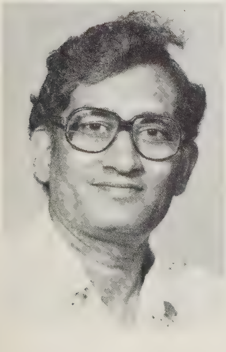

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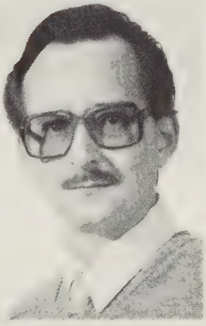

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Economics of selected on-farm adjustments for prairie grain farmers in response to rising future energy prices

A.V.S. Narayanan, H.T.M. Colwell, Y. Beaulieu and R.D. Zentner

INTRODUCTION*

Since the Arab oil embargo in 1973, the major producing sectors of the Canadian economy have been vulnerable to the vagaries of the world crude oil market, mainly controlled by the oil producing and exporting countries (OPEC). The primary agriculture sector, as an important user of diesel (11%) and gasoline (7%), was no exception. After following ad hoc policy measures — compensation, subsidy and priority allocation — to cushion the economy, in 1980 the federal government launched the National Energy Program (NEP), designed to provide Canadians with energy security, opportunity to participate in energy development and fairness in sharing the benefits of the nation's rich resources. The program's price regime[1] is designed to achieve energy independence by encouraging consumption of domestically plentiful natural gas and electricity energy in preference to oil.

This paper evaluates the economic feasibility of selected on-farm energy conservation adjustments in response to the energy price regime under the NEP for prairie grain farms during the 1981-86 planning period. For this purpose, we chose representative farms in Saskatchewan, which has the largest area and number of farms under grain and oilseeds. A study of the 1980 Farm Enumerative Survey shows that the energy component of operating expenses for grain and oilseed farms in Saskatchewan in the form of fuel oil, fertilizer, chemicals, electricity and heating oil, accounts for 39% of the total.

REPRESENTATIVE FARMS

Representative farms are specified on the basis of soil zones and size. The three predominant chernozemic soil groups of Saskatchewan — black, brown and dark brown — are considered. The brown and dark brown soil zones occur in semi-arid sections of the province with average annual precipitation ranging from 30 cm to 35 cm. The black soil zone, on the other hand, occurs in the sub-humid parkland section, with annual rainfall ranging from 38 to 46 cm. Summer fallowing is practiced as an integral part of soil moisture management and for weed control in all three soil zones. For each soil zone, two sizes of farm are considered — average and large.[2] The resources available to these farms, the current crop-fallow ratios, and the cropping pattern were determined from the statistics of the 1976 Census of Agriculture for Saskatchewan (Table 1). Inventories for each of these representative farms were also drawn up, but as of the 1980 crop year (Appendix 1). The net worth is specified at 80% for the average farm and 85% for the large farm in accordance with the high level of equity observed for prairie grain farms.

ADJUSTMENT OPTIONS

Three types of adjustment are considered in this study: 1. altering the use of land and allocation of crops with no change in production technology or fuel types used, 2. altering the production techniques but using the conventional fuel types and 3. substituting with natural gas by-product fuels (propane) as full or partial replacement for conventional fuel in conjunction with equipment modifications.

Land Use and Crop Allocation

Adjusting the land use mix. Summer fallowing, a common practice in the prairies, requires the use of heavy fuel-intensive machinery throughout the summer. By altering the proportion of land left for summer fallow, the fuel cost burden can be moderated. The representative farm types use one-half fallow and one-half crop in the brown soil zone, one-third fallow and two-thirds crop in the dark brown soil zone, and one-quarter fallow and three-quarters crop in the black soil zone. Keeping in view the soil moisture and machinery limitations, the adjustment options considered for evaluation are one-third and two-thirds for brown soil, one-quarter and three-quarters for dark brown soil and continuous cropping for black soil.

* This article was originally prepared in 1982 and was based upon information available at that time.

[1] This price regime allows for (a) the crude oil price to increase to a maximum of 75% of the average world price by 1986, (b) the price ratios of natural gas to oil to fall significantly over time and (c) the electricity price to rise at a rate 1.2% above the rate of increase in Consumer Price Index (CPI).

[2] Farms with a large land base are included in the analysis in order to evaluate the economic significance of size and scale.

TABLE 1. REPRESENTATIVE FARMS BY SOIL ZONE

	Soil Zones		
	Brown	Dark Brown	Black
Climatic Zones	Semi-arid	Sub-semi-arid	Sub-humid
Annual rainfall (cm)			
Average	30	35	42
Range	15-66	15-70	36-48
Crop/fallow rotation	1/2 / 1/2	2/3 / 1/3	3/4 / 1/4
Farm size (ha)			
Average	395	395	243
Large	729	648	486
Crop percentages			
Wheat	88	80	62
Barley	7	10	19
Oats	4	8	11
Rapeseed	1	1	6
Flaxseed	—	1	2
Permanent labor person-years	1.5	1.5	1.5

Adjusting the crop mix ratio. It is assumed here that altering the crop mix ratio would lead to fuel savings because of the differences in energy efficiencies with which individual crops are produced. In this respect, the Study of the 1980 Farm Enumerative Survey (referred to earlier) shows that in Saskatchewan the average expenditure per hectare on fuel and oil for wheat (cereal) farms in 1979 is only $8.85 compared with $9.90 for grain and oilseed farms and $11.55 for oilseed farms. Accordingly, increasing cereal production to 98% of the total cropped area is considered. However, this adjustment is relevant only to the black soil zone, where the cereal crop area is below 98%. The crop:fallow ratio for the soil zone will remain the same as in the base situation.

Altering Production Techniques

Eliminating the swathing operation. From the point of view of energy use, non-swathing saves one field operation, resulting in fuel savings. Swathing, however, as commonly practiced in all three soil zones, protects the farmer from shell-out losses of the mature crop because of wind, storm and rain, and is generally regarded as yield insurance. The yield reduction is therefore inevitable, the extent of which varies by region and year. Here we assume a standard reduction of 8% in yield for all the representative farms.

Reduced-tillage technology. An agricultural technique that has recently entered western Canadian agriculture is minimum or zero tillage. This involves replacing tillage operations in part or completely with the application of appropriate herbicides. The major advantage here is the reduction of machine hours and fuel use. These savings, however, are offset by increased chemical costs. Experimental results of minimum or zero tillage on brown soils at Lethbridge, Alberta have shown average yields increasing up to 6% as a result of nutrient and water conservation. The reduced tillage program considered here is represented by reduction of tillage operations to one operation in the brown and dark brown soil zones, and to two operations in the black soil zone. All post-harvest and pre-seed tillage operations are replaced by a more intensive herbicide program.[3] Stubble-in crops are planted with a discer and packer rather than conventional double disc or hoe drill.[4] The costs of the chemicals and their application at 1980 prices are estimated at $62/ha for the brown soil zone, $74/ha for the dark brown soil zone and $86/ha for the black soil zone (based on conservative estimates). The yields are assumed to be equal to those from normal tillage operations.

Substitute Fuels

One of the objectives of the NEP is to encourage consumers to use domestically produced natural gas by-products (propane), available at a lesser cost, as a substitute for oil. A mixture of diesel and propane (80:20) for the diesel tractors and 100% propane substitution for gasoline trucks are considered. For substitution, engines have to be fitted with conversion systems at an additional cost, estimated to run between $1500 to $1800 for tractors and $1300 for gasoline trucks (government subsidy excluded). The cost of on-farm storage and handling of propane is not included as the necessary facilities are assumed to be locally available and their cost reflected in the price of propane.

[3] Chemicals used here are very expensive compared with the more conventional herbicides, amounting to more than 60% of the program costs. The chemicals used are Paraquat and Round-up.

[4] Stubble-in crops are crops which result from seeds being left in a field because no post-harvest and pre-seed tillage operations have been performed since the previous crop year.

According to available technical information, the overall performance is reduced by 20% for converted gasoline engines and 4% for propane-diesel engines because of the lower energy content of propane. The main advantage is the dependable and adequate supply of propane at 20 to 25% lower cost than that of diesel or gasoline.

ANALYTICAL MODEL

The 1980 updated version of the Zentner Dryland Crops Simulation Model[5] is used for analysis. The model is designed to simulate results of dryland crop production alternatives for a period of up to 10 years. The model selects the best production plan with calculations based on the maximum net worth of the farm over the planning period, given the restrictions placed on resources (land, buildings, machines and finances), on crops, crop management systems and schedules of operation, on expected prices for inputs and products and on the production functions. As output, the model provides detailed tables summarizing crop-production performance measures for the entire planning period, the performance measures being quantity produced and resources used on area cropped. It also provides data on financial performance in terms of debt-asset positions, return on equity, net farm income, total receipts and expenses by input item, investment change, interest charges and debt changes, and on productivity in terms of average yields and nutrient consumption per hectare.

ANALYSIS PROCEDURE

The analysis procedure consists of five steps.

1. Setting up the model for the base runs of the six representative farms for the 1981-86 planning period and obtaining the base run simulation results.
2. Averaging the base run results for the planning period and developing a set of four performance measures: (a) input costs per hectare cropped — fertilizer and chemicals, fuel and oil, additional hired labor and interest payments; (b) input-output ratios — quantity per tonne produced, and value per dollar of crop receipts for energy input items (fuel and oil, fertilizer and chemicals, and labor; (c) net farm income per hectare cropped; and (d) percentage return on equity.
3. Deriving the average base performance measures for the two farm sizes by weighing the respective performance measures by soil zone with the proportional distribution of farms by soil zone[6] as derived from the 1976 census. These relative weights are used to take into account the variations in energy consumption by soil zone.
4. Setting up the runs with the adjustment options as proposed; carrying out steps 1, 2 and 3 as above for each adjustment run, and deriving the set of average performance measures by farm size.
5. Comparing the performance measures for the adjustment options with the base run performance measures and drawing inferences.

Required Specifications

Prices. Prices of wheat, barley, oats, flaxseed and rapeseed over the planning period (1981-86), the base year prices for energy inputs (diesel, gasoline, propane, nitrogen and phosphorus), the change in price indexes for general farm inputs, building replacement value, machinery replacement value, fuel price, fertilizer price, custom rate, and hired labor rate over the planning period for the model are shown in Table 2. They include current and forecast prices for the future period. These price and cost specifications remain constant throughout the analyses, thereby rendering the model results for the various options comparable for analysis.

Base run. The inventory set-up (Appendix 1), crop specifications (Table 1), and other operational information (Table 3) for the representative farms for the base runs are designed to represent farm business operation under normal patterns of fuel use and changing price situations (Table 2).

Adjustment runs. The selected energy adjustments are introduced by altering the corresponding specifications in the model, for example, altering the land use mix from one-quarter fallow and three-quarters crop to continuous cropping by appropriately changing the land-use specification. All the remaining specifications are kept at the base-run level. The specification alterations used under the adjustment options and the results are given in Tables 4 and 5.

RESULTS AND DISCUSSION

The mean planning period performance measures for the base and five adjustment situations for the representative average and large farm in Saskatchewan are summarized in Tables 4 and 5. The results focus mainly on the use and cost of energy inputs and comparisons on net farm income and return on equity.

The additional labor cost per hectare cropped represents the extent of paid-out cost for hired labor, and any variations in it would represent labor substitution. Likewise, the increase or decrease of interest payment per cropped hectare would indicate a change in the borrowings required to add to or reduce inventory (equipment) in response to adjustments. In fact, the interest charge per hectare for the average farm exceeds that of the large farm by over $7.4 because of a higher debt:asset ratio, accounting primarily for the large difference in net farm income per hectare between them.

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[5] Complete documentation of the model and the input forms are available from the authors.

[6] The relative weights for the dark brown, brown and black soil zones are 0.15, 0.3 and 0.55 for the average farm, and 0.15, 0.25 and 0.6 for the large farm.

TABLE 2. PRICE AND COST SPECIFICATIONS

Item	Years 1981	1982	1983	1984	1985	1986
Crop ($/t)						
Wheat[1]	201.7	184.5	201.0	224.9	239.9	234.4
Rapeseed[1]	279.5	274.3	306.9	313.9	315.7	308.6
Flaxseed[1]	329.5	275.2	344.3	307.9	331.5	272.0
Barley[1]	123.6	94.2	124.5	90.0	74.4	147.4
Oats[1]	72.6	64.2	67.4	90.1	73.3	64.2
Fuel ($/L base price)						
Diesel[2]	0.219					
Gasoline[2]	0.219					
Propane[2]	0.169					
Fertilizer ($/kg base price)						
Nitrogen[3]	0.546					
Phosphorus[3]	0.546					
Change rates in prices (1980 = 1.0)[4]						
General farm input price	1.113	1.246	1.396	1.599	1.714	1.902
Building replacement value	1.120	1.254	1.478	1.699	1.920	2.169
Machinery replacement value	1.104	1.232	1.386	1.533	1.754	1.965
Fuel price	1.363	1.714	2.019	2.369	2.681	3.025
Fertilizer price	1.090	1.210	1.355	1.504	1.669	1.853
Custom rate	1.070	1.154	1.260	1.386	1.524	1.677
Hired labor rate	1.070	1.070	1.145	1.236	1.347	1.466
Interest rates (percentage)						
Short term	18.0					
3-year loan	17.5					
5-year loan	17.0					
10-year loan	16.5					
15-year mortgages	15.5					
20-year mortgages	15.5					
30-year mortgages	15.5					

[1] Based on Statistics Canada farm gate prices for Saskatchewan and available model forecasts — namely, Agriculture Canada's Food and Agriculture Regional Model. All prices are stated in nominal terms.

[2] Based on 1981 prices for Regina, Saskatchewan

[3] Based on Saskatoon spot prices for nitrogen and phosphorus fertilizers

[4] All price change rates except for fuel are based on unpublished forecasts for internal use from Agriculture Canada. The fuel-price change rates are based on NEP projections.

Altering Crop-Fallow Allocation

The crop-fallow adjustment is considered at two levels depending on the intensity of cropping, i.e., the ratio of cropland to total land. The low-crop intensity represents an average increase of 20% in cropland over the base situation, for example, from one-half fallow and one-half crop to one-third fallow and two-thirds crop and the high-crop intensity represents an over 25% average increase in cropland, for example, from one-half fallow and one-half crop to one-quarter fallow and three-quarters crop. While the feasibility of low-crop intensity is not limited by any conditions, the feasibility of high-crop intensity allocation depends on adequate soil moisture build-up and availability of extra equipment. While the model can satisfactorily determine and provide the additional equipment needed, the soil moisture, if found deficit, would reduce productivity.

Comparisons of results of the average farm for base and adjustment situations (Table 4) indicate that stepping up the crop intensity generally leads to an increase in the use of energy-based inputs (fertilizer and chemicals) and a decrease in the use of energy inputs (fuel oil), as well as additional labor and interest payments over the base situation, although varying slightly between low- and high-crop intensity allocations. The costs per hectare cropped for fuel and oil, additional labor and interest payments show a reduction of 25%, 11% and 23%, respectively, stemming from spreading the use of available labor and equipment effectively over the increased cropland base. The slight increase in cost per hectare of fertilizer and

TABLE 3. FARM OPERATIONAL SPECIFICATIONS

	Soil Zones		
	Brown	Dark Brown	Black
Starting period for spring operations	April 9-22	April 23-May 5	May 6-20
No. of pre-seed tillage operations			
Fallow land	1	2	2
Stubble land	2	2	1
Post-harvest fall tillage operations (yes/no)	No	Yes	No
No. of summer fallow tillage operations	4	5	6
Canadian Wheat Board sale (percentage)	100	100	100
Residual soil N (kg/ha)			
Fallow land	82	86	96
Stubble land	45	45	49
Residual soil P (kg/ha)			
Fallow land	18	19	21
Stubble land	19	17	18

Source: Based on studies from Agriculture Canada at Lethbridge Research Station, Alberta, and at the Land Resource Institute, Ottawa, Ontario.

chemicals can be attributed to the need for increased nitrogen supplementation after reduced summer fallowing. The input-output measures also confirm the above by clearly showing increasing levels of ratios for fertilizer and chemicals (quantity and value) and decreasing ratio levels for fuel and oil over the base situation. The net income per hectare cropped shows a slight improvement under low-crop intensity, but declines about 12% under high-crop intensity, apparently because of reduced productivity resulting from high-crop intensity with deficit moisture.

For the large farm, the comparisons of performance measures (Table 5) are largely similar to those for the average farm with respect to energy-based inputs (fertilizer and chemicals) and direct-energy (fuel and oil) inputs. The additional labor cost and interest payment per hectare cropped, however, exceeds that of the base situation — especially the interest charges which increase more than 20%. This is attributable to the costs of financing the purchase of additional equipment, and expenses to operate a large, additional cropped area. The equipment inventory of the large farm is generally at an optimum, and expansion of cropland requires more inventory. With regard to the net farm income per hectare cropped, results similar to those for the average farm are obtained.

Altering Crop-Mix Ratio

The results of altering the crop-mix to 98% cereal crops (wheat, barley and oats) are shown in Table 4 for the average farm and in Table 5 for the large farm. Comparison of performance measures with the base situation reveals that all energy input efficiencies are almost unaffected by the change in crop mix for both the average and large farms (compare columns 1 and 4 in Tables 4 and 5). The average net farm income for the planning period, however, has increased slightly over that of the base situation.

Elimination of Swathing Operation

The results of non-swathing, which assumes a yield reduction of 8%, are given in Tables 4 and 5. Comparison with the base situation reveals that for the average farm there is an appreciable decrease in fuel cost per hectare cropped and fuel use per tonne of crop produced. The fertilizer use per tonne of crop produced, however, increases because of the assumed decrease in productivity. Overall, the net income per hectare cropped for the average farm decreases by 17%. For the large farm, however, the cost and ratio measures do not show any significant change from the base situation. The net income per hectare, however, declines 14%.

Reduced Tillage Technology

From the results of the reduced tillage analysis (Tables 4 and 5) the following points are evident: (a) an almost 100% increase in cost per hectare and use per dollar of produce for fertilizer and chemical inputs because of the expensive chemical program of weed control, (b) appreciable decrease in costs per hectare and rate of use for fuel and oil because of the elimination of many tillage operations, for both average and large farms and (c) moderate decreases in net incomes per hectare — 7% in the case of the large farm and 13% in the case of the average farm.

Fuel Substitution

The performance measures under the partial fuel substitution strategy are shown in Tables 4 and 5. A comparison with the base situation reveals that propane fuel has replaced all gasoline and part of diesel, at a lower cost per hectare cropped as well as at lower input:output ratios. The borrowed capital investment to modify engines increases the interest charges, but, on the whole, a 7% increase in net income per hectare cropped above the base situation is obtained in both farm sizes (Tables 4 and 5).

CONCLUSIONS

Conclusions from this paper are based on the evaluations of economic feasibility of selected on-farm energy conservation adjustments, considering the established NEP energy price regime and ad hoc forecasts for grains and other input prices — all in nominal terms — over the 1981-86 planning period for representative average and large prairie farms. For the economic feasibility of the five selected adjustment strategies we can conclude the following:

1. Cropping intensification leads to improvement in energy cost and use efficiency rates, but can also greatly enhance total consumption of conventional fuels, fertilizers and chemicals because of increased cropping and reduced summer fallowing. Despite these improvements, the net income per hectare cropped declines for the large farm mainly because of reduced soil productivity, which is due to intensive cropping under moisture deficit conditions. Moreover, this adjustment calls for change in the traditional system of summer fallowing, and at the aggregate level, arrangements to market the extra production entering the market.
2. Shifting to 98% production of wheat, barley and oats offers no cost or use economies, although, because of relative price advantages for wheat, its net income per hectare shows slight improvement. However, if a substantial part of the extra grain production enters the market, this advantage could be nullified because of depressed prices.
3. Elimination of swathing (machinery and related operations) and consequent yield reduction (8% as assumed) could lead to appreciable savings in interest charges and fuel use (approximately 6% on a per-unit basis), therefore resulting in lower costs. However, because of yield decreases, net income is also depressed.
4. With reduced tillage technology, substantial conventional fuel and oil savings (up to 25% on a per unit basis) are available. Despite the heavy cost of the chemical program under this option, the net incomes per hectare are not very much reduced. However, reduced tillage technology is still experimental and requires further feasibility testing as more research results become available.
5. Substituting with diesel-propane mix for tractors and propane for gasoline trucks is by far the most feasible and desirable option. With the fuel intake rates remaining at the same level as in the base situation, the composition of fuels used undergoes a very desirable change from diesel-gasoline (60:40) to diesel-propane (50:50). Consequently, substitution of 50% fossil fuels by natural gas by-product fuels is achieved. Despite increases in finance charges for necessary equipment modifications, a gain of about 6-7% in net income per hectare is also realized, largely because of the price advantage of domestically produced propane fuel.
6. With respect to the farm sizes, the conclusions noted above vary only very slightly. Large farms are generally affected slightly less when net incomes drop and slightly more when net incomes increase in response to adjustment options. This can be attributed primarily to optimal use of the equipment inventory and spreading the overhead costs on a larger cropped area.

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TABLE 4. PERFORMANCE MEASURES FOR BASE AND ADJUSTMENT SITUATION[1] — AVERAGE FARM

		Crop-fallow[2] Allocation					
	Base[3]	Low Crop Intensity	High Crop Intensity	Crop[4] Mix	Swathing[5] Elimination	Reduced[6] Tillage	Fuel[7] Substitution
1. Cost per ha cropped ($)							
Fertilizers and chemicals	63.6	65.2	63.7	63.5	63.6	103.4	64.3
Fuel and oil	28.3	21.9	21.2	28.3	23.5	21.3	25.7
Additional hired labor	6.4	5.6	5.7	7.2	7.3	7.2	7.2
Interest charges	20.0	16.0	14.8	20.0	19.3	22.9	20.05
2. Input:output ratios							
(a) Quantity ratio							
Fertilizer (kg/t)	26.8	34.4	39.3	26.0	28.8	27.3	27.2
Diesel and gasoline (L/t)	23.1	20.6	23.1	22.7	21.6	17.8	—
Propane (L/t)	—	—	—	—	—	—	12.3
Diesel (L/t)	—	—	—	—	—	—	12.2
Labor (hr/t)	1.6	1.6	1.7	1.7	1.5	2.7	1.8
(b) Value ratio (per $ of crop receipts)							
Fertilizer and chemicals	0.182	0.221	0.227	0.184	0.186	0.294	0.184
Fuel and oil	0.08	0.074	0.077	0.079	0.072	0.061	0.073
3. Net farm income per ha cropped ($)[8]	83.3	84.5	73.3	85.6	72.3	77.4	86.3
4. Return on equity (%)	12.94	12.61	12.75	12.85	11.98	12.62	13.11

[1] Averaged over the planning period, further weighted by the proportions of the number of farms under each soil zone in Saskatchewan as in the 1976 Census.

[2] The crop:fallow land ratios are adjusted upward — by one step for "low-crop intensity" and by two steps for "high-crop intensity."

[3] Model run with base specifications.

[4] Alteration of cropping percentages such that 98% of the cropland is devoted to wheat, barley and oats.

[5] Deletion of swathing machinery and pre-harvest swatching operation; and reducing soil productivity index by 8%.

[6] Deletion of post-harvest pre-seed tillage and summer fallow operations; increasing cost of chemical program per hectare on summer fallow.

[7] Changing the prices of diesel and gasoline corresponding to prices of diesel-propane mix and propane, respectively; adjusting field efficiency of tractors and trucks.

[8] Net farm income = Total cash receipts + WGSA payments + Insurance Appeal payments – (Total crop expenses + change in value of inventory + interest payments). WSGA payments and insurance appeal payments are payments to compensate for price-income instability and crop damage due to disease and weather. These are not applicable to this analysis.

TABLE 5. PERFORMANCE MEASURES FOR BASE AND ADJUSTMENT SITUATION[1] — LARGE FARM

		Crop-fallow[2] Allocation					
	Base[3]	Low Crop Intensity	High Crop Intensity	Crop[4] Mix	Swathing[5] Elimination	Reduced[6] Tillage	Fuel[7] Substitution
1. Cost per ha cropped ($)							
Fertilizers and chemicals	68.7	68.9	67.9	68.4	68.4	105.1	71.0
Fuel and oil	28.5	23.9	22.1	28.6	26.7	20.4	24.9
Additional hired labor	4.1	4.2	4.3	4.2	3.9	4.2	4.1
Interest charges	12.5	15.3	15.2	12.6	12.4	14.0	12.7
2. Input:output ratios							
(a) Quantity ratio							
Fertilizer (kg/t)	26.3	36.0	37.0	25.7	28.7	26.2	26.8
Diesel and gasoline (L/t)	23.8	22.9	22.6	23.3	23.4	16.7	—
Propane (L/t)	—	—	—	—	—	—	13.1
Diesel (L/t)	—	—	—	—	—	—	11.9
Labor (hr/t)	1.7	1.8	1.7	1.7	1.8	1.4	1.9
(b) Value ratio (per $ of crop receipts)							
Fertilizer and chemicals	0.197	0.268	0.231	0.198	0.217	0.300	0.188
Fuel and oil	0.081	0.082	0.083	0.082	0.081	0.058	0.070
3. Net farm income per ha cropped ($)[8]	105.0	108.3	93.6	107.2	89.0	93.8	111.7
4. Return on equity (%)	15.24	13.67	13.88	14.18	14.51	14.65	14.40

[1] Averaged over the planning period, further weighted by the proportions of the number of farms under each soil zone in Saskatchewan as in the 1976 Census.

[2] The crop:fallow land ratios are adjusted upward — by one step for "low-crop intensity" and by two steps for "high-crop intensity."

[3] Model run with base specifications.

[4] Alteration of cropping percentages such that 98% of the cropland is devoted to wheat, barley and oats.

[5] Deletion of swathing machinery and pre-harvest swatching operation; and reducing soil productivity index by 8%.

[6] Deletion of post-harvest pre-seed tillage and summer fallow operations; increasing cost of chemical program per hectare on summer fallow.

[7] Changing the prices of diesel and gasoline corresponding to prices of diesel-propane mix and propane, respectively; adjusting field efficiency of tractors and trucks.

[8] Net farm income = Total cash receipts + WGSA payments + Insurance Appeal payments – (Total crop expenses + change in value of inventory + interest payments). WSGA payments and insurance appeal payments are payments to compensate for price-income instability and crop damage due to disease and weather. These are not applicable to this analysis.

APPENDIX 1

Representative Farm Inventory 1980[1]

Items	Brown Soil Zone		Dark Brown Soil Zone		Black Soil Zone	
	Average	Large	Average	Large	Average	Large
Cultivator	28′ (1978)	36′ (1978)	20′ (1977)	28′ (1977)	16′ (1978)	24′ (1977)
Blade	20′ (1976)	28′ (1976)	16′ (1976)	20′ (1975)	—	—
Rod weeder	36′ (1977)	44′ (1977)	20′ (1975)	28′ (1977)	14′ (1975)	24′ (1974)
Harrow	28′ (1975) 40′ (1975)	36′ (1975) 52′ (1975)	20′ (1977) 40′ (1977)	28′ (1977) 48′ (1977)	16′ (1974) 36′ (1977)	24′ (1973) 48′ (1976)
Packer	—	—	—	—	14′ (1972)	24′ (1971)
Discer	—	—	—	—	16′ (1972)	24′ (1971)
Hoe drill	21′ (1976)	28′ (1976)	—	—	—	—
Press drill	—	—	18′ (1975)	24′ (1975)	16′ (1975)	24′ (1974)
Sprayer	60′ (1974)	75′ (1974)	50′ (1974)	60′ (1976)	40′ (1976)	60′ (1975)
Swather PTO	20′ (1976)	24′ (1976)	15′ (1976)	18′	12′ (1973)	18′ (1972)
Combine SP	50″ (1976)	55″ (1976)	50″ (1976)	55″ (1976)	40″ (1975)	55′ (1974)
Truck	½ t (1978) 2 t (1975)	½ t (1978) 2 t (1968) 3 t (1975)	½ t (1978) 2 t (1975)	½ t (1978) 2 t (1967) 3 t (1975)	½ t (1979) 1 t (1975)	½ t (1978) 3 t (1974)
Auger	37′ (1974)	37′ (1974) 39′ (1971)	37′ (1974)	35′ (1972) 37′ (1973)	35′ (1973)	37′ (1972)
Tractor	90 hp (1971) 130 hp (1977)	110 hp (1971) 205 hp (1977)	75 hp (1970) 110 hp (1977)	75 hp (1970) 130 hp (1977) 185 hp (1978)	50 hp (1972) 75 hp (1976)	75 hp (1971) 130 hp (1975)
Grain Storage						
1000 bu (50 t)	—	—	—	—	—	1 (1987)
2000 bu (100 t)	1 (1985)	2 (1985) (1988)	1 (1988)	2 (1986) (1988)	1 (1988)	1 (1988)
3000 bu (150 t)	1 (1987)	2 (1986) (1987)	1 (1987)	1 (1987)	1 (1990)	1 (1990)
4000 bu (200 t)	1 (1989)	1 (1989)	1 (1989)	2 (1989) (1990)	—	1 (1989)
5000 bu (250 t)	2 (1991) (1994)	3 (1991) (1993) (1994)	2 (1993) (1994)	3 (1991) (1991) (1994)	2 (1995) (1990)	3 (1991) (1991) 1994)
Machine storage						
144 m²	1 (1990)	—	1 (1990)	—	1 (1990)	1 (1990)
216 m²	—	1 (1990)	—	1 (1990)	—	—
20-yr debt	$23 750 (1979)	$35 000 (1970)	$22 000 (1979)	$35 000 (1979)	$25 000 (1975)	$25 000 (1979)
10-yr debt	$23 600 (1979)	$35 000 (1979)	$21 000 (1979)	$35 000 (1979)	$24 000 (1973)	$25 000 (1979)
3-yr debt	$22 700 (1979)	$30 000 (1979)	$20 000 (1979)	$30 000 (1979)	$20 000 (1978)	$20 000 (1977)

[1] For all farm equipment, sizes and year purchased are shown in parentheses. For all storage structures, the number and the year due for replacement are shown in parentheses. For all debt items, the year in parentheses shows the year that the loan was taken.

Source: As developed by Russel and Colwell.

Effects of rising energy costs on beef feedlot operators

Irwin Nemetz

INTRODUCTION*

Rising energy costs are affecting all areas of agricultural production. Beef producers are no exception, especially those who are involved in the production of part or all of their own feed. Ordinarily, energy use is not a significant factor in finishing cattle. It is limited to the transportation of animals and supplies, lighting, feed mixing and feeding itself. However, if home-produced are used, energy can become a significant cost factor in beef production. Because some feeds require more energy inputs than others, increased energy prices can have both short- and long-term effects on cattle rations and rates of gain in common use.

METHODOLOGY

In this study, a linear programming model is used to examine the effects of rising energy costs on the optimal cropping and feeding program of eastern Canadian feedlots. The model, which was developed at the University of Guelph, has both crop production and beef finishing activities.[1] Feed can be either produced or purchased.

I shall investigate two situations, the direct effect of rising fuel prices and the effect of fuel prices combined with increases in the prices of nitrogen-based fertilizers. Nitrogen is the only farm input considered in the investigation because it has energy as a main component in its price. Fuel and nitrogen-fertilizer prices are increased gradually from their 1981 levels up to those originally anticipated by the end of 1985. Nitrogen-price increases were calculated solely on the basis of nitrogen's energy component, with no account taken of other factors such as dealer and manufacturers' margins, transportation, supply and demand relationships, etc.

Table 1 shows the price levels 1 through 9 for fuel and fertilizer considered in this study. Recent developments in the world oil and fertilizer markets indicate that such high price levels will not occur until much later in this decade. All other costs, including those of purchased feed, and returns are held at their 1981 levels. As it concerns feed prices, this assumption may seem questionable to some readers but is justified for the following reasons. While it is probable that over the long run higher input prices will force adjustments in the farm price for feed ingredients, there is no clear adjustment path. However, due to the uncertainties involved, I felt that holding them constant (rather than try to forecast the magnitude of such price increases) would allow for a better examination of the energy-cost component independently of other factors.

Three crop rotations are considered, two of which are confined to southern Ontario, while the third can be applied anywhere in eastern Canada. Crops that can be grown include grain corn, corn silage, barley, wheat, alfalfa hay and haylage and soybeans, on a land base of 162 ha. Rotation 1 includes all of these cropping possibilities. In rotation 2, the maximum land base for soybeans is limited to 40.5 ha. Rotation 3 contains no soybeans or winter wheat. In all cases, 500 head of cattle are to be finished from starting weights of 150 kg for heifers and 200 kg for steers to full market weights of 450 kg for heifers and 500 kg for steers. The effects of rising energy prices on total fuel use, on animal rations and on gross farm income will be examined.

THE MODEL

The model I use is a single period linear programming model, which has provisions for crop production (as noted above) as well as beef finishing activities. Each crop has a fixed requirement for inputs, including fertilizer. Therefore, in the crop production section, the model evaluates changes in the product mix (i.e., what crops to grow) without evaluating changes in the process mix (i.e., how to grow the crops). Changes are possible in both the area devoted to individual crops and the total land base utilized. There are 16 beef finishing activities, with rates of gain ranging from 0.5 to 1.2 kg/head/day. These are chosen as representative of the National Academy of Sciences feeding requirements. Purchased feeds can include any of the grains, hay, soybean meal and feed grade urea.

TABLE 1. FUEL AND NITROGEN FERTILIZER PRICES USED

Price Level	Fuel Price ¢/L	Anhydrous Price ¢/kg
1	31.5	31.2
2	40.7	44.1
3	48.2	47.3
4	55.0	51.2
5	62.0	55.9
6	71.7	62.7
7	81.4	69.5
8	91.3	76.3
9	101.0	83.1

* This article was originally prepared in 1982 using the energy price information current at that time.

[1] Irwin J. Nemetz, A Linear Programming Farm Management Model for Ontario Cash Crop/Beef Feedlot Operators, unpublished M. Sc. thesis, University of Guelph, 1981.

An arbitrary fixed charge of 10¢/head/day is made to cover veterinary and other expenses in the feedlot. A confinement system is assumed, but it may not be appropriate for all feedlots. A complete cash-flow section allows for operating credit, personal consumption, loan repayments and all cash inflows and outflows.

RESULTS

Each rotation will be examined separately. Within each rotation, results are presented for changes in fuel prices only and for both fuel and nitrogen-fertilizer price increases. Tables 3 and 4 contain summaries of the effects on fuel use and gross farm income.

Rotation 1

In this situation, increasing only fuel costs, even by 220%, has little effect on the overall cropping program. A land base of 150 ha, which represents 93% of the total available, is utilized. Corn area, which because of its heavy fuel use would be expected to sustain the greatest effect, decreases only 8% in a gradual fashion, with the reduction occurring in grain corn for cash sales. The area of barley increases 12% at the expense of corn and soybeans when fuel prices reach $0.55/L. Little change is noted at prices above this level. Total fuel use decreases only 5% over the total price range, showing the relative unimportance of fuel costs in overall production. Cattle rations and rates of gain remain fairly constant, with some reduction in grain corn and silage feeding, as their relative costs increase due to higher input prices.

Including fertilizer prices changes the results dramatically. Corn area decreases 66%, with only the silage crop remaining. The largest decrease (17%) occurs at price level 4 (fuel at $0.55/L and anhydrous at 51.2 ¢/kg) and when fuel and fertilizer prices are increased to level 7 (fuel at 81.4¢/L, anhydrous at 69.5¢/kg), a further decrease of 59% from the corn area of price level 4. Soybean area increases 18%, while that of barley increases 11%. The changes in area for soybeans occur at price level 7 and for barley at price level 4. Total fuel use decreases 7% over the entire price range. Again, cattle rations and rates of gain remain stable, with some increase in the use of purchased feedgrains, whose price is held constant.

Rotation 2

This rotation is the same as the first, except that soybeans are limited to a maximum of 40.5 ha. This is an arbitrary limit put in to make the farm plan realistic in terms of area devoted to a single crop. Again, if only fuel prices are considered, very little change occurs. Total fuel use decreases 1% on the land base of 150 ha. Corn use in the feeder diets decreases marginally, with a larger reduction at the upper fuel price. The corn is replaced by purchased wheat.

When fertilizer price increases are included, more dramatic changes occur. Again, the area of corn silage remains fairly constant but grain corn area decreases 35% at price level 4 and 78% at level 9. Total corn area decreases by 62.2%. Total fuel use decreases 14% over the price range on a land base reduced by 10%. Table 2 shows the change in land use that results from the price increases. Feeder diets contain less corn and rely more heavily on purchased cereal grains.

Rotation 3

This rotation, which contains no soybeans or winter wheat, would be applicable to the largest area in eastern Canada. When only fuel prices are considered, there is virtually no change in the cropping program chosen, which consists of 60% corn and 40% spring grains. However, there is only a 68% utilization rate of the total land base available. This figure is derived by the linear programming algorithm, which maximizes gross farm income without necessarily utilizing all resources. What in fact is being stated is that 68% of the land base is sufficient to meet the feed production needs of the feedlot and it is unprofitable to use the remaining portion for cash crop production. Overall fuel use declines only 2%. Ration composition changes slightly in the same pattern as in the previous rotations, that is, there is some reduction in corn and an increase in purchased cereal grains.

When price increases in fertilizer are combined with fuel-price increases, a different result emerges. While silage area remains constant, the area used to grow grain corn decreases in gradual steps, going from a starting level of 55 ha to 38 ha at level 2, 29 ha at level 4 and finally to

TABLE 2. LAND USE PATTERN WITH INCREASED FUEL AND FERTILIZER PRICES

Price Level	Total Land	Corn	Soybeans	Barley	Wheat	Alfalfa
			ha			
1	149.8	47.7	40.5	37.3	20.2	4.0
2	149.8	47.7	40.5	37.3	20.2	4.0
3	149.9	47.2	40.5	37.8	20.2	4.0
4	138.5	34.1	40.5	39.6	20.2	4.0
5	138.5	34.1	40.5	39.6	20.2	4.0
6	138.5	34.1	40.5	39.6	20.2	4.0
7	134.4	30.2	40.5	39.5	20.2	4.0
8	134.4	30.1	40.5	39.5	20.2	4.0
9	134.3	18.4	40.5	51.0	20.2	4.0

TABLE 3. EFFECT OF FUEL PRICE INCREASES ON FUEL USE AND GROSS FARM INCOME

Fuel Price Level	Fuel Price	Rotation 1 (All Crops) Fuel Use (Base = 100)	Rotation 1 (All Crops) Farm Income (Base = 100)	Rotation 2 (Soybeans ≤ 40 ha) Fuel Use (Base = 100)	Rotation 2 (Soybeans ≤ 40 ha) Farm Income (Base = 100)	Rotation 3 (No Soy or Winter Wheat) Fuel Use (Base = 100)	Rotation 3 (No Soy or Winter Wheat) Farm Income (Base = 100)
	¢/L						
1	31.5	100	100	100	100	100	100
2	40.7	100	99.1	100	99.1	100	99.2
3	48.2	99.9	98.2	100	98.2	100	98.4
4	55.0	96.5	97.4	100	97.4	99.8	97.7
5	62.0	95.3	96.6	98.8	96.6	98.3	97.0
6	71.7	95.2	95.5	98.8	95.4	98.3	96.0
7	81.4	95.2	94.5	98.8	94.3	98.3	95.0
8	91.3	95.2	93.4	98.8	93.1	98.3	94.0
9	101.0	95.1	92.3	98.8	92.0	98.3	93.0

TABLE 4. EFFECT OF RISING FUEL AND NITROGEN FERTILIZER PRICES ON FUEL USE AND GROSS FARM INCOME

Fuel Price Level	Fuel Price	Anhydrous Price	Rotation 1 (All Crops) Fuel Use (Base = 100)	Rotation 1 (All Crops) Farm Income (Base = 100)	Rotation 2 (Soybeans ≤ 40 ha) Fuel Use (Base = 100)	Rotation 2 (Soybeans ≤ 40 ha) Farm Income (Base = 100)	Rotation 3 (No Soy or Winter Wheat) Fuel Use (Base = 100)	Rotation 3 (No Soy or Winter Wheat) Farm Income (Base = 100)
	¢/L							
1	31.5	31.2	100	100	100	100	100	100
2	40.7	44.1	99.9	98.3	100	97.5	97.4	97.0
3	48.2	47.3	99.8	97.1	99.9	96.2	97.4	95.9
4	55.0	51.2	95.9	96.0	92.2	94.9	96.2	94.9
5	62.0	55.9	94.7	94.8	91.0	93.6	94.7	93.7
6	71.7	62.7	93.1	93.3	91.0	91.9	94.5	92.1
7	81.4	69.5	93.1	91.8	88.3	90.3	94.5	90.6
8	91.3	76.3	93.1	90.3	88.3	88.6	94.2	89.0
9	101.0	83.1	92.9	88.8	86.3	86.9	93.6	87.4

26 ha at level 9. These decreases in grain corn are matched by offsetting increases in barley area, which increases from 40 ha to a final level of 69 ha. These changes in crop mix result in a decrease of 6.4% in overall fuel use on an unchanged land base.

DISCUSSION AND CONCLUSIONS

In a linear programming model of a beef feedlot that can either grow or purchase its feed, the effect of energy-price increases was investigated for different rotations. When fuel prices are raised in isolation from other input prices, the effects on total fuel use are rather small, ranging from 2 to 5%. The effect on income is in a similar range, from 7 to 9%. These are low figures considering that fuel prices were increased some 220%.

Of course, if energy prices increase, the cost of other farm inputs will not remain static. Including the effect of increased energy costs on fertilizer prices, the analysis shows more marked effects. There was the least effect with rotation 1, the high soybean area situation, with fuel use decreasing 7%. This is so because, with over half the available land devoted to soybeans, the farm is relatively independent of nitrogen-fertilizer price increases. When soybeans are limited, fuel use decreases 14% and in the no-soybean situation, it drops 6%. The larger drop in fuel use in the latter situation occurs because in the first case a larger land base is used (149.8 ha versus 110.2 ha). Decreases in gross farm incomes are from 12 to 13%.

In the feedlot portion of the operation, there are only minor changes. There is virtually no change in the type of ration fed or rates of gain chosen. A high-concentrate diet consisting of grain, corn silage and alfafa hay is consistently chosen. A high level of nutrition is also the consistent choice. These findings agree with the results of other similar work in the United States. While not directly comparable, several studies (Brokken et al, 1976, Brokken et al, 1980, Epplin et al, 1980) have examined the optimum roughage:concentrate ratio for feeder diets. All have concluded that high-concentrate diets are preferable, provided that cost ratios are realistic. This can be explained by two factors. First, it appears that nutritionally roughages are not a perfect substitute for concentrates in a diet, especially when stomach capacity becomes restrictive, resulting in a lower energy intake. Secondly, there is the time factor. An animal on a higher roughage diet requires a longer time to reach market weight. Costs in a feedlot can be divided into two types: weight-related and time-related. Weight-related costs are those associated directly with achieving the desired weight gain (i.e., feed costs). Time-related costs are those that vary with the length of time spent in the feedlot (i.e., labor, veterinary, interest, etc.). With high interest rates, the cost of keeping animals longer is higher than any savings realized by lower direct feed costs of roughages, even with dramatically higher input prices for fuel and fertilizer. The latter has a proportionately larger impact on concentrate prices. With lower interest rates, there would be more adjustment in feeding practices.

As energy prices increase, there is a trend towards relying on purchased grains instead of home-produced feed. This is understandable since the price of purchased feed is held constant. It is difficult to predict what effect dramatic increases in energy costs will have on long-term feed costs. The task of predicting it is beyond the scope of this article, yet the validity of this analysis, as well as the ultimate effect of large energy-price increases on the beef-finishing sector, depend on the future course of feed prices.

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Energy conservation in Canadian greenhouses: an economic analysis

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BACKGROUND*

The National Energy Program announced in October 1980[1] together with the September 1, 1981, agreement between the governments of Canada and Alberta on average Canadian crude oil prices[2] and the National Energy Program Update of April 1982[3] constitute the structure for Canadian fossil fuel prices that greenhouse producers can expect through 1986.

In June 1982, Energy, Mines and Resources Canada[4] estimated annual average fuel prices for selected regions of Canada for No. 2 fuel oil used in residential heating and for No. 6 fuel oil and natural gas used in commercial and industrial installations. These estimated prices are listed in Table 1. They would occur if established programs and agreements were followed through in Canada and world prices would be at the assumed levels.

Prices are expected to increase significantly for all three fuels. By 1986, No. 2 fuel oil prices are projected to be around 45% higher than in 1982. No. 6 fuel oil prices are projected to rise more than 50% from their 1982 level, while natural gas prices are expected to increase around 30 to 50% during the same period.

The Ontario Greenhouse Advisory Committee reported that "the total fuel bill for 1980 is about $20 million or about 17% of farm gate value"[5] of Ontario greenhouse production. This fuel bill represented an estimated total fuel consumption of 6.0×10^6 GJ or $3.33/GJ of energy. This quantity of fuel would cost more than $3.78/GJ or over $22 million in 1982 and would rise to over $6.00/GJ or $31.9 million in 1986 if no adjustments were made and if the National Energy Program price increases were to be realized.

* This article was prepared during the fall of 1982 using the price information and energy price scenarios current at that time.

[1] Energy, Mines and Resources Canada, *The National Energy Program: 1980, Report EP 80-4E* (Ottawa: Supply and Services Canada, 1980)

[2] Government of Canada, *Memorandum of Agreement Between the Government of Canada and the Government of Alberta Relating to Energy Pricing and Taxation* (Ottawa: Supply and Services Canada, September 1981)

[3] Energy, Mines and Resources Canada, *The National Energy Program: Update 1982* (Ottawa: Supply and Services Canada, 1982)

[4] Market Analysis and Statistics Division, Energy Strategy Branch, Department of Energy, Mines and Resources, *National Energy Program Update 1982: Supplementary Information on Canadian Energy Supply/Demand Outlook, 1981-2000* (Ottawa: Supply and Services Canada, June 1982)

[5] Ontario Greenhouse Advisory Committee, *An Energy Management Strategy for Ontario Greenhouses* (Toronto: Ontario Greenhouse Advisory Committee, November 1981)

The method developed for this article requires that one specify a future price scenario. If the reader prefers a price scenario other than the one shown in Table 1, its future prices can be directly substituted for the corresponding prices in Table 1 and the subsequent calculations performed in the same manner as shown below.

HEATING-COST ESTIMATES FOR THE 1982-86 PERIOD

Greenhouse operators purchase fuel with specific energy contents. Engineers suggest that No. 2 fuel oil contains 38.9 MJ/L of heat, No. 6 heavy fuel oil 41.8 MJ/l, and natural gas 37.1 MJ/m^3.[6] However, when these fuels are burned, some of the heat is lost through the flue and from the surface of boiler piping, etc. before they warm the greenhouse production environment. Oil-fired furnaces, even when well adjusted, are deemed to convert only 65% of the potential heat in fuel oils into heat for the greenhouse; that is, 35% of the potential heat in fuel oil is lost without serving any productive function. Natural gas furnaces are slightly more efficient at 70% conversion.[7] Often one encounters claims of 80% efficiency. It is possible for a furnace mechanic to adjust a burner unit, measure the temperatures of the flue gases and calculate that the burning efficiency is 80%. However, it is very important to realize that burner efficiency over an entire heating season is less because the furnace shuts down when the desired temperature in the greenhouse is reached. At the beginning and near the end of the heating season, a furnace shuts down frequently when the heat load is small relative to the furnace's maximum capacity. These sorts of losses can be lessened by various techniques and equipment but some heat loss is inevitable.

In the following analysis, the previously mentioned conversion efficiencies of 65% and 70% have been used, resulting in assumed thermal contents of 25.3 MJ/L for No. 2 and 27.2 MJ/L for No. 6 heating oils and 26.0 MJ/m^3 for natural gas.

Using the fuel-price estimates shown in Table 1 and the above energy relationships, it is possible to derive the cost of a gigajoule (GJ)[8] of heat produced in an oil-fired or gas-fired system for various provinces (Table 2). Again, if other furnace efficiencies are in order, they can be substituted for those used above and the corresponding data can be calculated.

[6] H.A. Jackson, Engineering and Statistical Research Institute, Research Branch, Agriculture Canada, *Energy Conservation in Greenhouses, Report I-277* (Ottawa: Supply and Services Canada, April 1981)

[7] Memorandum of Agreement, *op. cit.*

[8] *Ibid.*

TABLE 1. FORECAST ENERGY PRICES IN CANADA, 1982-86, BY REGION AND FUEL TYPE[1]

Region or Province	Fuel Type[1]	Unit	Year 1982	1983	1984	1985	1986
Atlantic	No. 2 Oil	¢/L	29.2	33.0	36.5	39.9	42.7
	No. 6 Oil	¢/L	20.7	24.0	27.2	30.4	33.1
	Natural Gas	$/GJ	6.05	6.67	6.77	7.30	7.89
Quebec	No. 2 Oil	¢/L	29.6	33.4	36.9	40.2	42.9
	No. 6 Oil	¢/L	20.5	23.5	26.4	29.4	32.0
	Natural Gas	$/GJ	4.94	5.48	6.01	6.63	7.22
Ontario	No. 2 Oil	¢/L	29.0	33.7	36.1	39.5	42.2
	No. 6 Oil	¢/L	19.3	22.2	25.0	27.9	30.4
	Natural Gas	$/GJ	4.07	4.54	5.02	5.57	6.10
Manitoba	No. 2 Oil	¢/L	29.0	32.6	36.0	39.3	41.9
	No. 6 Oil	¢/L	20.4	23.2	25.9	28.8	31.3
	Natural Gas	$/GJ	4.26	4.64	5.04	5.51	6.04
Saskatchewan	No. 2 Oil	¢/L	29.0	32.7	36.1	39.4	42.1
	No. 6 Oil	¢/L	19.9	22.6	25.2	27.9	30.3
	Natural Gas	$/GJ	3.13	3.40	3.69	4.03	4.44
Alberta	No. 2 Oil	¢/L	28.5	32.1	35.5	38.8	41.4
	No. 6 Oil	¢/L	19.9	22.5	25.0	27.6	29.9
	Natural Gas	$/GJ	2.65	2.84	3.06	3.31	3.66
British Columbia	No. 2 Oil	¢/L	29.2	32.9	36.4	39.7	42.3
	No. 6 Oil	¢/L	19.4	22.1	24.6	27.3	29.7
	Natural Gas	$/GJ	3.64	3.89	4.18	4.51	4.98

[1] Price for No. 2 Oil is the price to residential consumers;
No. 6 oil price is the commercial price;
the natural gas price is commercial user price.

Source: Market Analysis and Statistics Division, Energy Strategy Branch, Department of Energy, Mines and Resources, *Supplementary Information on Canadian Energy Supply/Demand Outlook, 1981-2000*, Ottawa, June 1982. Table 35 pp. 59-65.

Growers can expect to pay between $16/GJ and $17/GJ for No. 2 heating oil by 1986. Heating with No. 2 oil will be substantially more expensive than with either No. 6 oil or natural gas. The estimated costs for natural gas in 1986 range from a low of $5.23/GJ in Alberta to a high of $11.27/GJ in the Atlantic region. The cost for growers using No. 6 oil ranges from $10.92/GJ in British Columbia to $12.17/GJ in the Atlantic region.

ECONOMIC ASPECTS OF ENERGY CONSERVATION

A greenhouse grower faced with heating costs that are expected to rise by nearly half over the next 4 years may ask the question: how much can I afford to invest in energy conservation measures? Three major factors must be considered:

— the province or region where the greenhouse is located,
— the cost of investment funds and
— the amount of heat conserved by the investment.

For each preceding factor, several alternatives exist. Consequently, the number of possible combinations grows very rapidly. In the following discussion the relevant data for a few selected cases are presented in tables, accompanied by a few broad general comments.

Location

In Canada, temperatures vary from one geographical location to another. Meteorologists have developed a heating degree normal technique for expressing these variations and reflecting their magnitude. Usually the base temperature used is 18°C (65°F). One heating degree-day results for each degree that the daily mean temperature is below 18°C. No heating degree-days are counted when the mean temperature is 18°C or higher. The cumulative heating degree-day total is a measure of the heating requirement and hence, fuel requirement.

TABLE 2. PROJECTED HEAT COST BY REGION AND FUEL TYPE, 1982-86[1]

Region or Province	Fuel Type	Year 1982	1983	1984	1985	1986
				($/GJ)		
Atlantic	No. 2 Oil	11.54	13.04	14.43	15.77	16.88
	No. 6 Oil	7.61	8.82	10.00	11.18	12.17
	Natural Gas	8.64	9.52	9.67	10.43	11.27
Quebec	No. 2 Oil	11.70	13.20	14.59	15.89	16.96
	No. 6 Oil	7.54	8.64	9.71	10.81	11.76
	Natural Gas	7.06	7.83	8.59	9.47	10.31
Ontario	No. 2 Oil	11.46	13.32	14.27	15.61	16.60
	No. 6 Oil	7.10	8.16	9.19	10.26	11.18
	Natural Gas	5.81	6.49	7.17	7.96	8.71
Manitoba	No. 2 Oil	11.46	12.89	14.23	15.53	16.56
	No. 6 Oil	7.50	8.53	9.52	10.59	11.51
	Natural Gas	6.09	6.63	7.20	7.87	8.63
Saskatchewan	No. 2 Oil	11.46	12.92	14.27	15.57	16.64
	No. 6 Oil	7.32	8.31	9.26	10.26	11.14
	Natural Gas	4.47	4.86	5.27	5.76	6.34
Alberta	No. 2 Oil	11.26	12.69	14.03	15.34	16.36
	No. 6 Oil	7.32	8.27	9.19	10.15	10.99
	Natural Gas	3.79	4.06	4.37	4.73	5.23
British Columbia	No. 2 Oil	11.54	13.00	14.39	15.69	16.72
	No. 6 Oil	7.13	8.13	9.04	10.04	10.92
	Natural Gas	5.20	5.56	5.97	6.44	7.11

[1] Seasonal heating efficiencies: No. 2 fuel oil, 65%, No. 6 fuel oil, 65% and natural gas, 70%.

1.0/GJ = 1.0 gigajoule = 10^9 joules = 1000 Megajoules = 1000 MJ

The Meteorological Applications Branch of the Canadian Atmospheric Environment Service publishes monthly and annual estimates of heating degree-day normals below 18°C[9] for numerous locations throughout Canada. Average annual heating degree-day information for selected Canadian locations is shown in Table 3.

Heating-season degree-days values (Table 3, second column) were derived by subtracting the values for the summer months — June through September — from the annual heating degree value for each location. This is done to reflect the fact that no heat is normally required in Canadian greenhouses during the summer months. Victoria has a heating season degree-day value of 2752, prairie locations have values between 5000 and 6000, southern Ontario locations have values in the 3000-to-4000 range, while those in the Maritimes range between 3700 and 4700. The heating-season degree days have also been expressed as an index (Table 3, third column).

A major portion of the Canadian greenhouse industry (both flowers and vegetables) is in southern Ontario in or near Hamilton, Toronto, Toronto-Malton, and Windsor. Hence, an index of 100 represents the average heating-season degree-day value (3693) for these four locations. The index values in Table 3 were obtained by dividing the heating-season degree-day value for a specified location by 3693.

The index value represents the quantity of heat that two identical greenhouses would use if one were at a specified location and the other in the base location of southern Ontario. For example, the index value for Regina is 158 and the index value for Penticton is 92. One would interpret these values to mean that on average a greenhouse located at Regina would require 58% more heat than a similar one located in southern Ontario. Similarly, a Penticton greenhouse would require 8% less than if it were located in southern Ontario.

The next stage of analysis is to change the heating requirement as measured by the index into an annual heating demand measure in energy terms (MJ/m^2) for each location.

[9] *Supplemental Heating Degree-Day Normals Below 18°C — Based on the Period 1941-70*

TABLE 3. SUPPLEMENTAL HEAT REQUIREMENTS FOR SELECTED CANADIAN LOCATIONS

	Annual Heating Degree-Days	Heating Season Degree-Days[1]	Estimated Annual Heat Index	Demand
				GJ/m^2
Newfoundland				
Gander	5 127	4 548	123	3 284
St. John's (Torbay)	4 911	4 469	121	3 418
Prince Edward Island				
Charlottetown	4 210	4 327	117	3 124
Nova Scotia				
Halifax	4 210	3 380	105	2 804
Sydney	4 540	4 147	112	2 990
Yarmouth	4 120	3 708	100	2 670
New Brunswick				
Chatham	4 933	4 601	125	3 338
Fredericton	4 754	4 453	121	3 231
Moncton	4 788	4 442	120	3 204
Saint John	4 801	4 368	118	3 151
Quebec				
Bagotville	5 848	5 720	155	4 139
Montreal (Dorval)	4 532	4 351	118	3 151
Quebec City	5 125	4 811	130	3 471
Sept-Iles	6 213	5 984	162	4 325
Sherbrooke	4 811	4 519	122	3 257
Ontario				
Hamilton	3 788	3 653	99	2 617
Kapuskasing	6 443	6 115	166	4 432
Kenora	6 012	5 629	152	4 058
London	4 135	3 941	107	2 857
North Bay	5 395	5 200	141	3 765
Ottawa	4 734	4 517	122	3 257
Sudbury	5 370	5 020	136	3 631
Thunder Bay	5 816	5 341	145	3 872
Timmins	6 277	5 967	162	4 325
Toronto	3 747	3 619	98	2 617
Toronto (Malton)	4 154	3 966	107	2 857
Trenton	4 181	4 007	109	2 910
Windsor	3 645	3 534	96	2 563
Manitoba				
Dauphin	6 177	5 783	157	4 192
Winnipeg	5 967	5 640	153	4 085
Saskatchewan				
Regina	6 015	5 833	158	4 219
Saskatoon	6 160	5 969	162	4 325
Swift Current	5 564	5 350	145	3 872
Alberta				
Calgary	5 444	5 113	138	3 685
Edmonton	5 710	5 451	148	3 952
Grande Prairie	6 244	5 908	160	4 272
Medicine Hat	4 959	4 820	131	3 471

TABLE 3. SUPPLEMENTAL HEAT REQUIREMENTS FOR SELECTED CANADIAN LOCATIONS

	Annual Heating Degree-Days	Heating Season Degree-Days[1]	Estimated Annual Heat Index	Demand
				GJ/m²
British Columbia				
Fort Nelson	7 173	6 874	186	4 966
Penticton	3 605	3 393	92	2 456
Prince George	5 432	5 432	147	3 925
Prince Rupert	3 965	3 965	107	2 857
Vancouver	3 136	2 832	77	2 056
Victoria	3 079	2 752	75	2 003
Yukon Territories				
Whitehorse	6 973	6 973	189	5 046
North West Territories				
Inuvik	10 301	10 301	279	7 449
Yellowknife	8 718	8 718	236	6 301

[1] Heating-season degree-days are calculated by subtracting the monthly degree-day values for June through September from the annual degree-day value except where a location had more than 300°C degree-days for June or September, in which case the month value was not deducted from the annual. For Prince George and Prince Rupert, British Columbia and Whitehorse, Inuvik, and Yellowknife, it was deemed appropriate to use the annual degree-days for heating season degree-days.

Source: Supplemental Heating Degree-Day Normals Below 65 F° — Based on the Period 1941-70. Climatology Division, Canadian Meteorological Service, 315 Bloor Street West, Toronto, Ontario. February 5, 1971. CDS 2-71. Converted to Celsius temperature scale.

Recently, the Ontario Greenhouse Advisory Committee[10] published the following information pertaining to the annual heat demand for glass gutter-connected greenhouses at selected southern Ontario locations (see Table 4). The arithmetic average for Windsor, Toronto (Malton) and Vineland is 2667 MJ/m^2.

It was decided to use 2670 MJ/m^2 as an average annual heat demand equivalent to an index of 100. Estimated annual heat demands for other locations are calculated according to the formula: 2670 $\times$ (Index for the location : 100) Annual Heat Demand.

TABLE 4. ANNUAL HEAT DEMAND

Location	Annual Heat Demand (MJ/m²)
Toronto	2600
Ottawa	3200
Windsor	2600
Vineland	2700
London	3000

[10] *An Energy Management Strategy for Ontario Greenhouses, op. cit.*

Capital Investment Levels for Energy Conservation Techniques

The estimates shown in Table 5 are the nominal heating cost for greenhouses over the next five years if no energy conservation adjustments were to be undertaken.

If a grower wants to recuperate his or her investment in energy conservation equipment and technology, the present value of his or her expected fuel savings must exceed the present value of all extra expenses. Expected fuel savings will be the percentage savings in fuel use multiplied by the number of years over which it is saved, subsequently multiplied by the present value of fuel costs in those years.

The approach used in this analysis is to identify the maximum capital investment in energy conservation adjustments which would be equal to the present value of the fuel savings.

The present-value concept involves an understanding of the time value of money. To understand this concept, consider the following question. How much money must a greenhouse operator invest at the beginning of 1982 to pay for his or her fuel in each year through 1986? Assuming he or she received 15% interest, he or she must have \$1.00 to purchase each dollar's worth of fuel for 1982, \$0.8696 to purchase a dollar's worth in 1983, \$0.7561 for 1984, and \$0.6575 for 1985 and \$0.5718 for 1986.[11] We can apply

[11] See the Appendix for the present value of one dollar paid one to nine years in the future for whole-number interest rates from 11% to 20%.

TABLE 5. ESTIMATED GREENHOUSE HEATING COSTS[1] IN CURRENT DOLLARS, 1982-86, AT SELECTED CANADIAN LOCATIONS

	Fuel Type	Heating Costs[2] 1982	1983	1984	1985	1986
				$/m^2		
St. John's	No. 2 Oil	39.44	44.57	49.32	53.90	57.70
	No. 6 Oil	26.01	30.15	34.18	38.21	41.60
	Natural Gas	29.53	32.54	33.05	35.65	38.52
Charlottetown	No. 2 Oil	36.05	40.74	45.08	49.27	52.73
	No. 6 Oil	23.77	27.55	31.24	34.93	38.02
	Natural Gas	26.99	29.74	30.21	32.58	35.21
Halifax	No. 2 Oil	32.36	36.56	40.46	44.22	47.33
	No. 6 Oil	21.34	24.73	38.04	31.35	34.12
	Natural Gas	24.23	26.69	27.11	29.25	31.60
Fredricton	No. 2 Oil	37.29	42.13	46.62	50.95	54.54
	No. 6 Oil	24.59	28.50	32.31	36.12	39.32
	Natural Gas	27.92	30.76	31.24	33.70	36.41
Quebec	No. 2 Oil	40.61	45.82	50.64	55.15	58.87
	No. 6 Oil	26.17	29.99	33.70	37.52	40.82
	Natural Gas	24.51	27.18	29.82	32.87	35.79
Montreal	No. 2 Oil	36.94	41.67	46.06	50.16	53.54
	No. 6 Oil	23.80	27.28	30.65	34.13	37.13
	Natural Gas	22.29	24.72	27.12	29.90	32.55
Toronto	No. 2 Oil	29.99	34.86	37.34	40.85	43.65
	No. 6 Oil	18.58	21.35	24.05	26.85	29.26
	Natural Gas	15.20	16.98	18.76	20.83	22.79
Windsor	No. 2 Oil	29.37	34.14	36.57	40.01	42.75
	No. 6 Oil	18.20	20.91	23.55	26.30	28.65
	Natural Gas	14.89	16.63	18.38	20.40	22.32
Winnipeg	No. 2 Oil	46.81	52.66	58.13	63.44	67.65
	No. 6 Oil	30.64	34.85	38.89	43.26	47.02
	Natural Gas	24.88	27.08	29.42	32.15	35.25
Regina	No. 2 Oil	48.35	54.51	60.21	65.69	70.20
	No. 6 Oil	30.88	35.06	39.07	43.29	47.00
	Natural Gas	18.86	20.50	22.23	24.30	26.75
Edmonton	No. 2 Oil	44.50	50.15	55.45	60.62	64.65
	No. 6 Oil	28.93	32.68	36.32	40.11	43.43
	Natural Gas	14.98	16.05	17.27	18.69	20.67
Medicine Hat	No. 2 Oil	39.08	44.05	48.70	53.25	56.79
	No. 6 Oil	25.41	28.71	31.90	35.23	38.15
	Natural Gas	13.16	14.09	15.17	15.42	18.15
Vancouver	No. 2 Oil	23.73	26.73	29.59	32.26	34.38
	No. 6 Oil	14.66	16.72	18.59	20.64	22.45
	Natural Gas	10.69	11.43	12.27	13.24	14.62

[1] Calculated using annual heat requirement taken from Table 3 and the heat costs shown in Table 2.

[2] Full heating season, October 1 to May 31, for fuel oil and natural gas.

TABLE 6. PRESENT VALUES OF FUEL COSTS, 1982-1986 AT SELECTED CANADIAN LOCATIONS DISCOUNTED AT 15% INTEREST BY TYPE OF FUEL[1]

Discount Factor		1982 1.000	1983 0.8696	1984 0.7561	1985 0.6575	1986 0.5718	Total[2]
	Type of Fuel	Present Value of Fuel Costs					
		$/m^2					
St. John's	No. 2 Oil	39.44	38.76	37.29	35.44	32.99	183.92
	No. 6 Oil	26.01	26.22	25.84	25.12	23.79	126.98
	Natural Gas	29.53	28.30	24.99	23.44	22.03	128.29
Charlottetown	No. 2 Oil	36.05	35.43	34.08	32.40	30.15	168.11
	No. 6 Oil	23.77	23.96	23.62	22.97	21.74	116.06
	Natural Gas	26.99	25.86	22.84	21.42	20.13	117.24
Halifax	No. 2 Oil	32.36	31.79	30.59	29.07	27.06	150.87
	No. 6 Oil	21.34	21.51	21.20	20.61	19.51	104.17
	Natural Gas	24.23	23.21	20.50	19.23	18.07	105.24
Fredricton	No. 2 Oil	37.29	36.64	35.25	33.50	31.19	173.87
	No. 6 Oil	24.59	24.78	24.43	23.75	22.48	120.03
	Natural Gas	27.92	26.75	23.62	22.16	20.82	121.27
Quebec	No. 2 Oil	40.61	39.85	38.29	36.26	33.66	148.06
	No. 6 Oil	26.17	26.08	25.48	24.67	23.34	125.75
	Natural Gas	24.51	23.64	22.55	21.61	20.46	112.77
Montreal	No. 2 Oil	36.94	36.24	34.83	32.98	30.61	171.60
	No. 6 Oil	23.80	23.72	23.17	22.44	21.23	114.36
	Natural Gas	22.29	21.50	20.51	19.66	18.61	102.57
Toronto	No. 2 Oil	29.99	30.31	28.23	26.86	24.96	140.35
	No. 6 Oil	18.58	18.57	18.18	17.65	16.73	89.71
	Natural Gas	15.20	14.77	14.18	13.70	13.03	70.88
Windsor	No. 2 Oil	29.37	29.69	27.65	26.31	24.44	137.46
	No. 6 Oil	18.20	18.18	17.81	17.29	16.38	87.86
	Natural Gas	14.89	14.46	13.90	13.41	12.76	69.42
Winnipeg	No. 2 Oil	46.81	45.79	43.95	41.71	38.68	216.94
	No. 6 Oil	30.64	30.31	29.40	28.44	26.89	145.68
	Natural Gas	24.88	23.55	22.24	21.14	20.16	111.97
Regina	No. 2 Oil	48.35	47.40	45.52	43.19	40.14	224.60
	No. 6 Oil	30.88	30.49	29.54	28.46	26.87	146.24
	Natural Gas	18.86	17.83	16.81	15.98	15.30	84.78
Edmonton	No. 2 Oil	44.50	43.16	41.93	39.86	36.97	206.87
	No. 6 Oil	28.93	28.42	27.46	26.37	24.83	136.01
	Natural Gas	14.98	13.96	13.06	12.29	11.82	66.11
Medicine Hat	No. 2 Oil	39.08	38.31	36.82	35.01	32.47	181.69
	No. 6 Oil	25.41	24.97	24.12	23.18	21.81	119.49
	Natural Gas	13.16	12.25	11.47	10.80	10.38	58.06
Vancouver	No. 2 Oil	23.73	23.24	22.37	21.21	19.66	110.21
	No. 6 Oil	14.66	14.54	14.06	13.57	12.84	69.67
	Natural Gas	10.69	9.94	9.28	8.71	8.36	46.98

[1] Full heating season from October 1 to May 31

[2] The sum of the present values for each respective year

these values to the nominal heating costs shown in Table 5 to calculate a present value of each year's heating costs for the duration of the National Energy Program. These computations are shown in Table 6. One can apply other factors corresponding to other interest rates and proceed to recalculate them. The amount of money shown in the "Total" column in Table 6, if deposited at 15% interest in January 1982, would be sufficient to purchase the fuel at the forecast cost and supply the heat requirements shown in Table 3.

Table 7 shows the estimated maximum investment in energy conservation technology that a greenhouse operator could afford to bring about a 10% reduction in heating costs over the 5-year period during which the National Energy Program is in effect. These estimates range from $\$4.70/m^2$ to $\$22.46/m^2$. If an energy-conserving technique reduces heat loss by 5%, the maximum investment would be one-half the value shown in Table 7; 20% savings would be double the amount shown.

It is important to note that when two or more energy conservation techniques are applied to the same greenhouse structure,

— the total cost of combined techniques is the sum of their respective costs, i.e., Total Cost of A and B = Cost of A + Cost of B

— the efficiency of the combination is the product of their individual efficiencies, i.e., Efficiency of A and B = (Efficiency of A) × (Efficiency of B),

$$\text{where Efficiency} = 1.0 - \frac{\text{Energy Savings as \%}}{100}$$

and Energy Savings are relative to a well maintained, well managed glass greenhouse and where no energy-saving techniques have been applied previously.

The Ontario Greenhouse Advisory Committee Report included a summary of the energy-conservation potential of various technologies. It is reproduced here as Table 8 so that the reader can perform calculations particular to his or her own situation and compare the estimated fuel savings with the associated investment costs.

TABLE 7. MAXIMUM AFFORDABLE[1] INVESTMENT FOR ENERGY CONSERVATION MEASURES TO EFFECT A 10% FUEL SAVINGS AT SELECTED CANADIAN LOCATIONS (15% INTEREST RATE, 5-YEAR PAYBACK)

	Fuel		
Location	No. 2 Oil	No. 6 Oil	Natural Gas
		$\$/m^2$	
St. John's	18.39	12.78	N.A.
Charlottetown	16.81	11.61	N.A.
Halifax	15.09	10.42	N.A.
Fredericton	17.39	12.00	N.A.
Quebec	14.81	12.57	11.28
Montreal	17.16	11.44	10.26
Toronto	14.04	8.97	7.09
Windsor	13.75	6.97	5.45
Winnipeg	21.69	14.57	11.20
Regina	22.46	14.62	8.48
Edmonton	20.69	13.60	6.61
Medicine Hat	18.17	11.95	5.81
Vancouver	11.02	6.97	4.70

[1] Repayable from reduced fuel costs on year-round operations

Interest rates and Energy Conservation Capital Investment Levels

Two related questions are suggested by the preceding discussions:

— By how much would the present value of fuel costs decrease (increase) if interest rates were 3% higher (lower)?

— By how much would the maximum affordable investment in energy conservation be affected?

Answering these questions entails computing estimates that correspond to each interest rate. However, a carefully designed example can quickly enhance one's understanding and demonstrate the underlying relationships. Since an 18% interest rate is 1.5 times a 12% interest rate, it would be fair to compare two locations where one location required approximately 50% more heat than the other. Table 3 shows an index value of 96 for Windsor and 145 for Thunder Bay. The present value of the projected 1982-86 fuel costs discounted at 12, 15 and 18% interest rates were calculated for Windsor and Thunder Bay and are shown in Table 9. The data demonstrate that

— a direct relationship exists between requirements and fuel costs; that is, a 50% increase in fuel requirements increases heating costs by 50%; compare Thunder Bay present value with Windsor present value.

— consequently, a location with a 50% higher fuel requirement (e.g., Thunder Bay) can afford to invest a corresponding 50% more for energy conservation technology and equipment than another location (e.g., Windsor).

— however, a 50% increase in interest rates (e.g., 18% vs 12%) reduces the maximum affordable investment by only 8%.

— therefore, interest rates do not seem to affect the feasibility of energy conservation technology as much as one may believe.

TABLE 8. ENERGY EFFICIENCY TECHNIQUES AND ENERGY SAVINGS

Technique	Equipment or Method	Range of Energy Savings[1]
		(%)
Reducing Thermal Conductance	Double glass (roof glazing)	20-40
	Double polyethylene (roof glazing)	20-40
	Thermal pane	10-20
	Double layered acrylic (roof glazing)	20-40
	Double layered polycarbonate	20-45
	Double polyethylene over glass	30-60
	Single polyethylene over glass	15-20
	Single polyethylene under glass	10-15
	Air blanket (double polyethylene under glass)	20-35
	Air tubes (deflatable air blankets)	15-30
	Lapseal	5-20
	Insulation of transmission mains	5-10
	External windbreaks	5-10
	Gable wall insulation	1-4
	Sidewall insulation – styrofoam-double glazing	2-6
	Insulation of perimeter footings	2-4
	Thermal blankets	10-35
Reducing Thermal Differential	Reducing air temperature	5-25
	Split night temperature	5-15
	Soil warming in combination with reduced air temperature	1-5
	Altered plating date	5-60
	Infrared heating	5-45
	Correct heating pipe placement	2-5
	Maintaining uniformity of air temperatures	5-10
	Precise control of temperature	1-5
	Alternative cool crops	10-40
	Changing cultivars	2-10
Optimizing Fuel Conversion	Efficient boilers	5-25
	Recapturing stack losses	2-10
	Using economizers	5-15
	Using retarders	2-7
	Preheating water boiler	2-5
	Insulating boilers	2-5
	Insulating boiler room	1-5
	Back draught louver on stacks	2-10
	Duty cycling of boilers	1-5
	Correct placement of unit heaters	2-4
	Hot water instead of steam	5-15
	Bar capping and general maintenance	1-5
	Repairing leaks in traps, etc.	1-5
	Painting heat exchanger pipes black	1-4
	Modulating burners	2-5
	Efficient electric motors	1-10
Reducing the Fuel Input per Unit Product	Movable benches	15-30
	CO_2 utilization	5-10
	Soilless production systems	0-20
	Multiple level shelving	20-50
	Smaller unit size	5-40
	Chemical sterilization or the use of aerated steam for disinfection of the soil	5-20
	Production of prefinished crops	10-50
	Growing cultivars with shorter cropping time	5-20

[1] The energy savings are those for a glass greenhouse where no other energy-saving techniques have been applied.

SUMMARY

Projected fuel oil and natural gas prices that Canadian greenhouse operators will likely pay between 1982 and 1986 were used to derive the cost of heat. These costs were then adjusted by using meteorological data to compensate for variation in geographic features at different Canadian locations; the derived costs are on a dollars-per-square-metre basis. Since energy conservation entails a modification of the greenhouse prior to realizing fuel savings — that is, a financial investment — the present value of expected fuel costs per square metre were derived. From these discounted fuel costs, the maximum affordable investment is derived by multiplying the percent fuel savings for a specified technique by the present value of fuel costs for a specified location and fuel.

CONCLUSIONS

Given that Canadian operators use No. 2 fuel oil to heat their greenhouses, they could, depending on where they are located, afford to invest $11.00/m^2 to $22.50/m^2 to effect a 10% fuel savings, assuming a 15% interest on borrowed funds and a 5-year payback period. For heavy fuel oil, the maximum affordable investment in energy-saving techniques is from $7/m^2 to $15/m^2 and for natural gas, the maximum investment level is $4.90/m^2 to $11.25/m^2. The location of a greenhouse in an area of low heat requirement reduces production costs but also reduces the maximum affordable investment in energy conservation technology.

Finally, the results of this study indicate that interest rates are relatively ineffective in varying the feasibility of energy conservation projects; that is, if a project is feasible at 15% interest, its feasibility will not be reduced much at 18% or enhanced much by 12% interest.

TABLE 9. PRESENT VALUE OF FUTURE FUEL COSTS, WINDSOR AND THUNDER BAY

Location	Fuel Type	Present Value of 1982-86 Fuel Costs Discounted At			Maximum Affordable Investment for Energy Conseration at Selected Interest Rates		
		12%	15%	18%	12%	15%	18%
			$/m^2			$/m^2	
Windsor	No. 2 oil	144.65	137.46	133.53	14.47	13.75	13.35
	No. 6 oil	92.57	87.86	85.33	9.26	8.79	8.53
	Natural gas	73.09	69.42	67.44	7.31	6.94	6.74
Thunder Bay	No. 2 oil	218.31	207.49	201.55	21.83	20.75	20.16
	No. 6 oil	139.84	132.74	128.93	13.99	13.27	12.89
	Natural gas	110.43	104.89	101.91	11.04	10.49	10.19

APPENDIX

PRESENT VALUE OF ONE DOLLAR PAID ONE TO NINE YEARS IN THE FUTURE DISCOUNTED AT SELECTED INTEREST RATES[1]

Interest Rate, r	Future Year, N 1	2	3	4	5	6	7	8	9
percent					– dollars –				
11	.9009	.8116	.7312	.6588	.5935	.5346	.4817	.4339	.3909
12	.8929	.7972	.7118	.6355	.5674	.5066	.4523	.4039	.3606
13	.8850	.7931	.6930	.6133	.5437	.4803	.4250	.3761	.3329
14	.8772	.7695	.6750	.5921	.5194	.4556	.3997	.3506	.3075
15	.8696	.7561	.6575	.5718	.4972	.4324	.3759	.3269	.2843
16	.8621	.7432	.6407	.5523	.4761	.4105	.3538	.3050	.2630
17	.8547	.7305	.6244	.5336	.4561	.3898	.3332	.2848	.2434
18	.8475	.7182	.6086	.5758	.4371	.3704	.3139	.2660	.2255
19	.8403	.7062	.5934	.4987	.4190	.3521	.2959	.2487	.2090
20	.8333	.6944	.5787	.4823	.4019	.3349	.2791	.2326	.1938

[1] Computed directly using the formula: Present value $= (1 + r)^{-N}$

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Farm energy use survey – preliminary results

Jim McKenzie and Irwin Nemetz

Energy is an important input in modern agriculture. The large increases in productivity exhibited by the agricultural production sector are based on energy to power machinery and as a feedstock to produce fertilizers and agricultural chemicals.

Despite energy's importance to agriculture, there is very little information concerning actual on-farm use. This means that it has been difficult to target energy-related programs and research effectively to those sectors of agriculture which most need them. In recognition of this gap in information, Statistics Canada, in cooperation with Agriculture Canada and Energy, Mines and Resources, conducted a Farm Energy Use Survey (FEUS) in July, 1982.

The survey consisted of a sample of 7000 farms with 1981 sales of over $5000 from across Canada. Cooperation by the farming community was exceptional. High participation rates and well thought-out answers indicated a good deal of interest among farmers on this topic.

The sample indicates that there were 237 000 farms in Canada with sales of over $5000 per annum. This is only slightly lower than the 1981 census figure of 243 000, which included some farms not in the FEUS sample (i.e., institutional farms, community pastures, etc.).

Overall, the preliminary results of the survey are revealing but not surprising. They confirm that farmers, while heavily dependent on gasoline and diesel fuel, are also important users of other fuels for special purposes, such as drying crops and heating farm buildings. The survey also yields some hard data on regional differences in energy use—a reflection of regional price differences, farm types, climatic differences and fuels available.

ENERGY EXPENDITURES AND USE

Of all the farms surveyed, 97% reported farm business expenditures on gasoline, 87% reported diesel purchases and 89% reported expenditures on electricity. Fuel oil was used on 24%, LPG (propane) on 15% and natural gas on 10% of the farms. Table 1 presents the percentage of farms that made energy purchases for the farm business. There is some regional variation. More prairie farms purchased diesel fuel than farms in other parts of the country. Natural gas use was highest in Alberta. New Brunswick had the largest number of farms purchasing wood.

Canadian farmers now use about 15% more diesel fuel than gasoline. However, in the prairies, this difference is closer to 30%. In the other regions of the country, gasoline and diesel uses are approximately equal.

Together, gasoline and diesel accounted for approximately 75% of all direct energy expenditures, while electricity accounted for about 15%. However, in Prince Edward Island, electricity accounted for 23% of total farm energy expenditures and in Saskatchewan, diesel fuel alone accounted for almost 50%. Together, Saskatchewan and Alberta account for about 60% of the gasoline and about 70% of the diesel fuel used on Canadian farms.

Although Alberta has the highest number of LPG users, Ontario and Quebec each used about 50% more and spent about twice as much as Albertan farmers on this fuel.

While most of the natural gas users are in Alberta, Ontario accounted for one-third of the expenditures and use of this fuel. In both quantity and value, Ontario was the largest user of electricity, accounting for almost 30% of the Canadian totals.

Total direct energy expenditures are the highest in Saskatchewan, followed closely by Alberta and Ontario.

Total Canadian and provincial farm business expenditures by energy type are presented in Table 2.

For most energy types, the amount purchased per farm reporting farm business expenditures varied substantially among provinces. Average gasoline purchases ranged from 3200 L/farm in Quebec to 9300 L/farm in Alberta. Average diesel purchases ranged from 2800 L/farm in Newfoundland to 10 600 L/farm in Alberta. Some of this variation can be accounted for by differences in the average farm size. However, even after taking the land area per farm into account, considerable variations remain in fuel use per hectare. Ontario used about 110 L/ha of gasoline and diesel combined while Saskatchewan used only 40 L/ha.

Average LPG use per farm reporting varied from 1200 L/farm in Newfoundland to 17 500 L/farm in Quebec. Ontario and Manitoba also reported high average levels of LPG use. Natural gas use per farm reporting was highest in Ontario and lowest in Saskatchewan. Fuel oil use per farm was highest in Newfoundland and lowest in Saskatchewan.

Electricity expenditures per farm averaged $840 for Canada as a whole but ranged from $457 in Saskatchewan to $2009 in Newfoundland. These averages were higher in eastern than in western Canada. This is partly due to price differences; for example, Manitoba and New Brunswick had about the same use rates but the average cost per farm was $400 higher in New Brunswick.

Table 3 presents the expenditures and quantities purchased per farm reporting such expenditures, for Canada and the provinces.

TABLE 1. FARMS REPORTING EXPENDITURES ON ENERGY

	Canada	Nfld	P.E.I.	N.S.	N.B.	Qué.	Ont.	Man.	Sask.	Alta	B.C.
Total number of farms with sales over $5000	237 177	244	2 199	2 329	2 111	32 049	56 947	24 215	60 906	46 232	9 945
%[1] farms reporting expenditures on:											
Gasoline	97	94	96	92	98	92	95	99	98	99	96
Diesel	87	68	87	82	86	87	84	92	94	91	74
LPG	16	8	15	11	10	11	11	13	15	28	17
Fuel oil	24	30	58	27	37	13	21	20	41	11	24
Natural gas	10	0	0	0	0	0	5	1	1	42	6
Electricity	89	83	96	89	93	96	93	86	85	86	84
Wood	1	2	4	4	11	1	1	2	1	0	2
Other	3	0	7	6	11	0	1	5	1	9	7

[1] The percentages are based on farm business portion only and therefore totals do not represent 100% of energy purchases, i.e., personal use is excluded.

CONCLUSIONS

This article has briefly outlined some of the data from the 1982 Farm Energy Use Survey. It is only a small fraction of the information available. In addition to data on energy expenditures, there is also information on the energy-consuming capital stock on farms (tractors, trucks, combines, self-propelled machinery, electric motors, grain dryers, etc.), irrigation, crop drying, building heating, management practices and nitrogen fertilizer use.

A Statistics Canada publication (Catalogue No. 21-519) contains the complete results of the survey. Persons or organizations wishing information can also contact Mr. Larry Murphy, Agricultural Statistics Division, Statistics Canada, Main Building, Tunney's Pasture, Ottawa, Ontario (613) 995-4895.

TABLE 2. FARM BUSINESS EXPENDITURES AND QUANTITIES PURCHASED BY ENERGY TYPE

	Canada	Nfld	P.E.I.	N.S.	N.B.	Qué.	Ont.	Man.	Sask.	Alta	B.C.
Gasoline											
$ 000	448 179	536	4 110	4 187	4 630	35 568	83 092	53 736	131 127	114 244	16 949
000 L	1 440 892	1 221	10 628	11 608	12 825	95 074	241 570	167 434	425 399	424 460	50 673
Diesel											
$ 000	464 646	167	3 329	2 753	2 774	32 156	75 966	62 255	157 620	114 611	13 015
000 L	1 640 481	478	10 232	8 262	8 135	107 670	258 895	210 053	548 767	446 149	41 840
LPG											
$ 000	45 264	9	172	130	225	13 377	13 320	5 351	4 786	6 937	957
000 L	229 573	24	696	570	967	62 370	64 415	28 569	24 681	42 599	4 652
Natural gas											
$ 000	34 887	0	0	0	0	0	12 029	319	581	20 458	1 500
000 L	17 710	0	0	0	0	0	5 900	172	266	10 499	873
Stove/furnace oil											
$ 000	46 818	259	1 102	1 242	1 141	6 059	21 398	2 323	9 153	2 711	1 430
000 L	178 683	803	3 809	4 951	3 945	23 839	82 299	8 960	35 547	11 231	5 299
Electricity											
$ 000	177 382	407	2 649	2 737	2 354	36 351	52 610	16 209	23 643	31 798	8 624
000 L	4 718 193	8 899	29 600	54 157	45 501	1 051 762	1 331 941	481 505	661 310	816 525	236 993
Total expenditures	1 217 176	1 378	11 362	11 049	11 124	123 511	258 415	140 193	326 910	290 759	42 475

TABLE 3. FARM BUSINESS ENERGY EXPENDITURE AND QUANTITIES PURCHASED PER REPORTING FARM

	Canada	Nfld	P.E.I.	N.S.	N.B.	Qué.	Ont.	Man.	Sask.	Alta	B.C.
	237 177	244	2 199	2 329	2 111	32 049	56 947	24 215	60 906	46 232	9 945
Gasoline											
Expenditure ($)	1 995	2 330	1 950	1 946	2 243	1 199	1 533	2 250	2 195	2 503	1 775
Quantity (L)	6 286	5 323	5 043	5 395	6 213	3 206	4 456	7 012	7 122	9 301	5 308
No. of farms reporting	229 221	229	2 108	2 152	2 064	29 658	54 216	23 879	59 732	45 637	9 546
Diesel oil											
Expenditure ($)	2 209	999	1 747	1 437	1 534	1 157	1 591	2 789	2 747	2 734	1 767
Quantity (L)	7 800	2 861	5 371	4 315	4 499	3 873	5 423	9 411	9 564	10 641	5 681
No. of farms reporting	210 321	167	1 905	1 915	1 808	27 797	47 737	22 321	57 379	41 928	7 364
LPG											
Expenditure ($)	1 212	429	519	508	1 065	3 757	2 100	1 652	531	545	518
Quantity (L)	6 147	1 207	2 091	2 229	4 573	17 518	10 157	8 818	2 741	3 348	2 827
No. of farms reporting	37 346	20	333	256	212	3 560	6 342	3 240	9 004	12 723	1 656
Natural gas											
Expenditure ($)	1 467	0	0	0	0	0	4 276	1 559	750	1 054	2 543
Quantity (GJ)	745	0	0	0	0	0	2 097	844	343	541	1 480
No. of farms reporting	23 786	0	0	0	0	0	2 813	204	774	19 405	590
Stove/Furnace Oil											
Expenditure ($)	830	3 619	865	1 995	1 480	1 484	1 752	476	367	524	608
Quantity (L)	3 169	11 214	2 988	7 958	5 120	5 837	6 739	1 836	1 345	2 171	2 255
No. of farms reporting	56 380	72	1 275	622	771	4 084	12 212	4 881	24 940	5 173	2 350
Electricity											
Expenditure ($)	841	2 009	1 251	1 317	1 205	1 180	994	777	457	796	1 037
Quantity (kWh)	22 368	43 967	13 979	26 068	23 298	34 129	25 171	23 068	12 785	20 442	28 499
No. of farms reporting	210 939	202	2 118	2 078	1 953	30 817	52 915	20 873	51 724	39 943	8 316
Average area per reporting farm (ha)	265.5	38.4	101.3	139.5	137.8	97.3	87.6	304.0	422.5	411.1	192.0

The potential of propane as a farm mobile fuel*

Dave Culver[1]

Farm operators and researchers have become increasingly interested in the application of alternative mobile fuels for the farm sector. This interest results from past and expected increases in the price of diesel fuel and gasoline, as well as a concern that the supply of imported crude oil could be interrupted, resulting in fuel shortages. Despite this interest in alternative mobile fuels, their use has remained a negligible portion of the total volume of fuel used on the farm.

The increased use of alternative fuels in the farm sector would help to improve Canada's energy security by reducing the need for crude-oil imports. The Canadian farm sector, which has approximately 1.67 million self-propelled vehicles, is a significant user of petroleum-based products. In 1981, Canadian farm operators purchased 1.44 GL[2] of gasoline and 1.64 GL of diesel fuel. Canadian farm operators purchased an average of 6286 L of gasoline and 7800 L of diesel fuel per farm.

Unlike alternative mobile fuels, propane has been extensively used on Canadian farms for stationary applications for a number of years, primarily in crop drying and space heating. In 1982, exports of propane from Canada were equal to almost 6400 m^3 of crude oil per day, or one-fifth of Canada's net crude-oil imports. Therefore, by diverting current propane exports to domestic applications, imports of crude oil could be reduced by a domestically produced energy source.

In this article, I intend to provide information to the propane industry, farm operators and policy makers on the potential of propane as an alternative transportation fuel by assessing

— the economics of propane conversions in the farm sector
— the potential of propane to reduce a farm operator's input expenses and help to alleviate the cost-price squeeze that many farm operators are experiencing and
— the extent to which propane as a mobile fuel in the Canadian farm sector will contribute to the government of Canada's goal of eliminating crude-oil imports.

The article is divided into five sections. In them I discuss mobile-fuel use by farm type and region, outlook for fuel prices, potential benefits and costs of propane conversions and the economics of propane conversions. Ultimately, I form some conclusions.

FUEL USE BY FARM TYPE AND REGION

The extent to which the use of propane as a mobile fuel will alleviate the cost-price squeeze of farm operators partly depends on the proportion that gasoline and diesel fuel contribute to the total input costs of farming operations. The greater the contribution of gasoline and diesel expenditures to total operating expenditures, the more significant will be an increase in energy productivity.

The highest expenditure on fuels is that of the farm operators in western Canada (Table 1). In 1980, their expenditures on fuels averaged $3236 per farm, or 10.2% of operating expenditures. Of the western provinces, Saskatchewan's expenditures on fuel are the largest; here fuels were the third most important operating expenditure. In central and Atlantic Canada, where livestock enterprises are relatively more important, expenditures on fuel are a smaller proportion of operating expenses. In Atlantic Canada expenditures for fuels were 5.9% and in central Canada 4.6% of all operating expenditures in 1980.

Fuel expenditures vary significantly among farm types (Table 1). Expenditures on fuel as a percentage of total expenses are highest for grain and oilseed operations in Atlantic and western Canada, averaging 11.2 and 11.5% of total operating expenses. Grain and oilseed operators in central Canada spend a smaller proportion on fuel, reflecting their greater tendency to mix livestock with cash crops.

Expenditures on fuels are much lower for livestock farmers than for crop farmers. In Atlantic Canada, fuel accounted for 5.1% and in central Canada 4.0% of the total operating expenses for livestock farm operators. In western Canada, livestock producers had an average expenditure of $2958 per farm, or 8.2% of the total operating expenditure. The higher expenditure on fuel for western livestock producers reflects the greater tendency of western livestock producers to grow their own feed. Within the livestock farm types, poultry and hog operations spent the smallest percentage on fuel.

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* This article was prepared using information available during the fall of 1982.

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[2] GL: gigalitres. 1 gigalitre = 1 billion litres.

TABLE 1. EXPENDITURES ON FUEL BY FARM TYPE, WESTERN, CENTRAL AND ATLANTIC CANADA, 1980[1]

Farm Type	Western Canada		Central Canada		Atlantic Canada	
	Expenditure Per Farm	Percentage Operating Expense	Expenditure Per Farm	Percentage Operating Expense	Expenditure Per Farm	Percentage Operating Expense
	$	%	$	%	$	%
All types	3236	10.2	1629	4.6	1554	5.9
Grain and oilseeds	3427	11.5	1893	6.9	1859	11.2
Wheat	3558	12.5	1133	9.8	3718	8.9
Coarse grain	2359	11.8	746	7.4	1750	14.9
Oilseeds	2837	10.7	1718	8.1	N/A	N/A
Corn	7385	6.9	2410	4.1	N/A	N/A
Mixed grains	4465	10.0	2214	7.7	1516	8.1
Fruits	N/A	N/A	1336	6.2	1132	8.9
Vegetable	N/A	N/A	2486	4.9	2991	7.6
Livestock	2958	8.2	1496	4.0	1260	5.1
Dairy	3323	6.8	1683	4.5	1642	4.9
Cattle and calves	2806	9.5	1120	6.5	720	9.4
Hogs	3827	5.5	1719	2.5	1680	3.5
Poultry	2390	2.5	2119	2.2	1679	2.6

[1] Exclude heating oil expenses.
N/A – Not available
Source: Unpublished data from Statistics Canada's 1981 Farm and Agriculture Enumerative Survey

OUTLOOK FOR FUEL PRICES

The economic benefits of converting to propane are largely determined by the price of propane relative to the prices of competing fuels. The greater the relative favorable price differential between propane and the competing fuels, the greater the incentive for farm operators to convert to propane use. In doing so, a farm operator must consider not only the present but also the expected price differential. The future price differential will be determined by a number of interrelated foreign and domestic factors.

Gasoline and Diesel Prices

The extent to which the world price for crude oil increases or decreases over the next few years will be a major factor in determining future Canadian gasoline and diesel prices. Canadian crude-oil prices are directly related to the international price of crude oil by agreements signed by the government of Canada and the producing provinces. These agreements tie the price of conventional oil produced in Canada to no more than 75% of the world price and provides the producer with world prices for new oil.

After a five-fold increase in real world oil prices in the past decade, there are indications that in the 1980s crude-oil price increases will be more moderate. In the *National Energy Program (NEP) Update,* which was released in June 1982, Energy Mines and Resources Canada predicted that the world crude-oil price will remain constant in nominal terms until the end of 1983, and then rise 2% a year in real terms until the end of 1986.

The Canadian blended crude-oil price, which is calculated from domestic and world oil prices, is expected to increase from $200/m^3$ in 1982 to $328/m^3$ in 1986. Until the end of 1983, increases in the blended-oil price will be a result of the price of conventional oil produced in Canada moving closer to world prices. These projections in crude-oil prices could, however, change dramatically, depending on such factors as OPEC solidarity, stability in the Middle East and the state of the world economy.

Farm and non-farm gasoline and diesel fuel prices for 1982 and projected prices for 1986 are presented in Table 2. The projected 1986 prices are based on crude-oil price increases as projected by the *NEP Update 1982*, but they could be altered by variations in the forecast price of crude oil or changes in provincial and federal taxes. Within provinces, significant differences can occur in petroleum prices, caused by such factors as different levels of competition and variations in transportation costs.

TABLE 2. ESTIMATES OF RETAIL GASOLINE AND DIESEL FUEL PRICES FOR ON-FARM AND OFF-FARM USE, PROVINCES AND ATLANTIC CANADA, 1982 AND 1986

Province or Region	Gasoline and Diesel Prices 1982 On-Farm Use	1982 Off-Farm Use[1]	1986 On-Farm Use	1986 Off-Farm Use[1]
	– ¢/L –			
British Columbia	37.8	42.7	54.5	62.9
Alberta	32.2	33.7	48.4	49.9
Saskatchewan	32.2	33.7	48.4	49.9
Manitoba	34.3	40.2	51.1	59.9
Ontario	35.0	42.5	51.1	62.6
Quebec	34.9	49.9	51.7	62.9
Atlantic region	35.5	41.5	52.3	61.3

[1] Price includes a 1.5 ¢/L federal excise tax which is rebated to farmers and commercial operators.

Sources: Energy, Mines and Resources Canada, *National Energy Program Update 82,* Energy, Mines and Resources Canada, *Energy Supply/Demand Outlook, 1981-2000,* 1982 and Agriculture Canada, *Internal Survey of Farm Fuel Prices* (unpublished), 1982

Propane Prices

Propane prices, unlike domestic crude-oil prices, are not controlled by the federal government. The outlook for propane prices is based largely on historical propane prices in Canada. Historically, the domestic wholesale propane price has been equal to or slightly lower than the domestic crude-oil price on an energy equivalency basis. Since the beginning of 1981, the wholesale price of propane has, however, been considerably below the domestic price of crude oil. In fact, for a period during 1982, the domestic wholesale price of propane was only slightly above the domestic natural-gas price on an energy equivalency basis.

The 1982-86 outlook for wholesale propane prices will depend on a number of factors. These include the U.S. propane price, natural-gas supplies, the state of the Canadian economy and future government policies concerning propane pricing and taxation. Although the government of Canada does not control propane prices directly, Energy Mines and Resources Canada is involved in monitoring them throughout the country. The price scenarios exhibited in Figures 1 and 2 are based on the historical relationship between propane prices and the prices of competing fuels.

Price scenario No.1 is based on depressed propane prices, similar to those of late 1981 and early 1982, continuing throughout the 1982-86 period. This scenario would be likely to occur if the recession were to continue and propane prices remain low in the United States. Scenario No.2 is based on a more rapid increase in propane prices so that in terms of energy content, the wholesale propane price is 85% of the projected crude-oil prices in Sarnia and 75% of them in Edmonton. This scenario is based on a slightly higher wholesale propane price in Sarnia than Edmonton, which reflects additional transportation costs. It is viewed as the most likely, given current market conditions in the propane industry. Scenario No.3 is based on a rapid recovery in propane prices so that by mid-1983, the wholesale price of propane in Edmonton and Sarnia will equal crude-oil prices on an energy equivalency basis.

The retail prices for propane for on-farm and off-farm transportation applications for 1982 and the forecast prices for 1986 are given in Table 3. These prices include applicable provincial taxes as well as distribution charges, which are assumed to increase 10% a year. Forecasts for 1986 propane prices are based on a continuation of current provincial policies regarding taxes on propane. As with the case of diesel fuel and gasoline, prices for propane are reported on a provincial basis for western and central Canada and on a regional basis for Atlantic Canada.

POTENTIAL BENEFITS AND COSTS OF PROPANE CONVERSIONS

The most obvious cost of converting a farm vehicle to propane use is the vehicle conversion cost. A typical gasoline-powered farm vehicle can be easily converted to run on propane by installing a pressurized propane tank, propane fuel-lock and filter, a vaporizer-pressure regulator and an air-propane gas carburetor. The conversion also involves some adjustments to the existing equipment such as the engine timing. The cost of such conversions by a recognized propane conversion dealer is approximately \$1600.[3] The cost of converting to propane use is partly offset by the Propane Vehicle Grant Program, which was established by the government of Canada to encourage the conversion of vehicles to propane use. The Program provides a taxable grant of up to \$400 a vehicle for converting commercial and farm vehicles.

[3] Prices used in this article were quoted by propane dealers and suppliers during June 1982. Current prices could vary from those reported in this article.

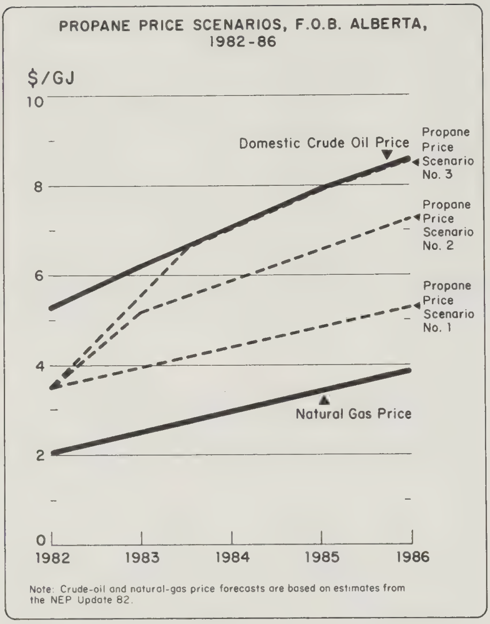

Figure 1

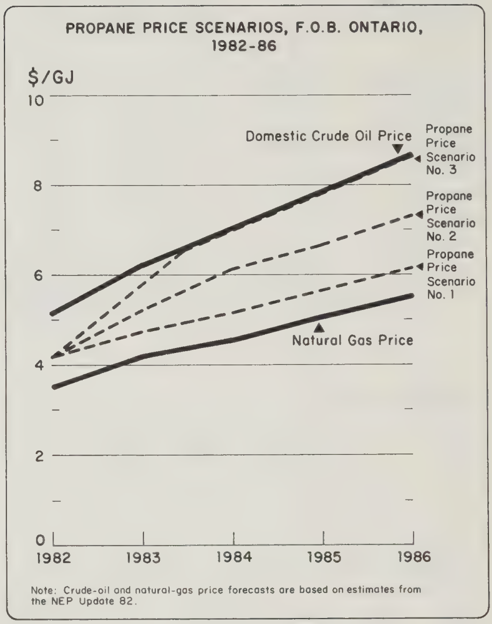

Figure 2

TABLE 3. PROPANE PRICES FOR ON-AND-OFF FARM USE, PROVINCES AND ATLANTIC CANADA, 1982 AND 1986

	1982[1]		1986					
			On-Farm Use			Off-Farm Use		
Province or Region	On-Farm Use	Off-Farm Use	Scenario No.1	Scenario No.2	Scenario No.3	Scenario No.1	Scenario No.2	Scenario No.3
				– ¢/L –				
British Columbia	21.0	21.0	29.8	33.5	37.8	29.8	33.5	37.8
Alberta	17.7	17.7	25.0	28.7	33.0	25.0	28.7	33.0
Saskatchewan	20.1	20.1	28.4	32.1	36.4	28.4	32.1	36.4
Manitoba	21.0	25.2	29.8	33.2	37.8	35.8	39.8	45.4
Ontario	19.2	19.2	26.8	39.7	33.0	26.8	29.7	33.0
Quebec	22.1	36.1	31.1	34.0	37.3	41.4	44.3	47.3
Atlantic	24.2	32.0	35.6	38.5	41.8	46.8	50.1	53.4

[1] Prices are approximately equal to the actual propane prices during June 1982.

Diesel-powered equipment can be converted to either a dual diesel-propane engine or a propane-powered one. In a dual diesel-propane engine, the propane is used to provide supplementary power during periods of high engine loads; the maximum amount of diesel fuel that can be replaced by propane is, however, only about 25%. This type of conversion costs approximately $1600. A diesel engine can also be converted to run entirely on propane. This conversion involves the installation of spark plugs and the removal of fuel injection equipment, as well as other engine modifications, and costs approximately $5000.

Unlike gasoline engine conversion, the conversion of diesel engines to propane use can cause uncertain and unreliable engine performance. Because of this problem, some farm machinery manufacturers will not honor engine warranties after a diesel engine has been converted to propane use. Until these systems have proven reliability and performance, the conversion of diesel vehicles to propane use is not a viable alternative for Canadian farms. The government of Canada is, however, funding research through the NEP to improve the technology of diesel engine conversions, which could result in diesel-to-propane conversions becoming a viable option in the coming years.

In many instances, a farm operator will be able to refuel propane-powered vehicles at one of the approximately 2600 propane vehicle refueling centres in Canada without any inconvenience. If this is the case, the total cost of converting a vehicle to propane use will be the engine conversion cost. However, for those farm vehicles that are used exclusively on the farm, it would be too costly and inconvenient to refuel propane vehicles off the farm. The conversion of vehicles that are used exclusively on the farm would therefore also involve the additional expense of an on-farm propane dispensing unit.[4]

The cost of establishing an on-farm fuel dispensing unit will vary considerably among different farming operations. Farms that use propane for space heating or crop drying may have excess propane storage capacity during the growing season. The operators of such farms can easily establish on-farm propane dispensing units by installing purchased pumping devices. The cost of a pumping device ranges from about $450 for a hand pump to $2000 for an electric one. The hand pump has the disadvantage of requiring 10 to 15 minutes of fairly strenuous effort to accomplish a fill-up.

If a farm does not use propane or does not have excess propane-storage capacity, a farm operator will also have to purchase a propane storage tank. The price of propane storage tanks can vary significantly. A small tank (1900 L) costs approximately $2000.

[4] In New Brunswick and Nova Scotia, a person must obtain a license in order to operate a propane dispensing unit. The qualifications make it very difficult for a farm operator to have an on-farm propane dispensing unit.

There are several advantages to propane that a farm operator should consider in evaluating propane as an alternative fuel. The most significant one is the possibility of reducing fuel costs. The per-litre saving in fuel is determined by the price differential between propane and gasoline, as well as the operating efficiency of the vehicle after the conversion. Since on a volume basis, propane contains a gross energy content of approximately 75% of gasoline, distance traveled per litre of fuel is generally lower with propane than with gasoline. However, due to its greater combustion efficiency than that of gasoline, propane is a more energy-efficient fuel; therefore, fewer units of energy are needed per kilometre than with gasoline. The efficiency of propane, which varies with driving conditions, will therefore determine the number of litres of propane required to replace a litre of gasoline. Under most driving conditions, it takes from 1.1 to 1.3 L of propane to replace 1 L of gasoline. The total savings in fuel expenditure will be directly proportional to the savings per kilometre. Therefore, heavily used vehicles will have the largest fuel savings.

Propane conversion may also result in additional savings since the combustion of propane produces almost no residues. This can result in fewer oil-filter and spark-plug changes. The use of propane also extends engine life. In some instances, the useful engine life could be almost doubled. Ontario has also provided significant additional savings by eliminating sales tax on propane vehicles.

ECONOMICS OF PROPANE CONVERSIONS

The economic analysis will consider three typical farm situations that a farm operator might encounter when deciding to convert to propane:

1. gasoline farm trucks being used primarily off the farm,
2. gasoline-powered farm machinery where there is excess propane storage capacity and
3. gasoline-powered farm machinery where there is no excess propane-storage capacity.

To evaluate the desirability of converting gasoline farm trucks and machinery to propane ones, payback periods and internal rates of return on an after-tax basis (using a marginal tax rate of 25%) were calculated for the three farm situations. The payback period provides an estimate of the time required to pay back the total cost of converting. In addition to the payback period, the analysis also considers the internal rate of return that accounts for the value of money. The required internal rate of return will vary among farm operators. In most instances an internal rate of return of under 15% would be unacceptable. The payback periods and internal rate of return were based on anticipated savings in fuel expenditures. The analysis did not account for potential savings due to reduced maintenance expenses or due to longer engine life, which may occur after converting to propane.

Conversion of Farm Trucks

The economics of converting farm trucks that are used primarily off the farm could be substantially different than for other farm vehicles. In many situations, a farm operator may be able to convert farm trucks without establishing an on-farm fuel-dispensing unit. The economics of converting farm trucks may also be substantially different than those for farm vehicles used exclusively on the farms, since in many provinces, the propane-gasoline price differential is considerably different for fuel used on the farm than for that used off the farm.

The economic analysis considered the desirability of converting farm trucks from gasoline to propane ones for three different levels of vehicle use. Infrequent, moderate and heavy vehicle use were based on the annual consumption of 1000, 2500 and 4000 L of fuel used off the farm. The estimated payback periods and internal rate of return for 1982 are given in Table 4. The analysis illustrates that for many farm operators in Ontario and western Canada, the conversion of heavily used gasoline trucks to propane use is an attractive economic investment. The conversion of moderately used gasoline farm trucks would also be of benefit to many farm operators in British Columbia and Ontario. The conversion of infrequently used farm trucks to propane use does not appear to be attractive in Canada.

The economic attractiveness of converting gasoline farm trucks to propane use in the coming years will depend to a large extent on the future level of propane prices. The forecast payback periods and internal rates of return for the conversion of heavily used gasoline trucks are analyzed for the three propane price scenarios (Table 5). With the low or moderate propane price scenario, the conversion of heavily used farm trucks to propane use in 1986 would be feasible for many farm operators in central

TABLE 4. PAYBACK PERIODS AND INTERNAL RATE OF RETURN FOR FARM TRUCK CONVERSION, PROVINCES AND ATLANTIC CANADA, 1982

Province or Region	Payback Periods[1] Infrequent Use	Payback Periods[1] Moderate Use	Payback Periods[1] Heavy Use	Internal Rate of Return[2] Infrequent Use	Internal Rate of Return[2] Moderate Use	Internal Rate of Return[2] Heavy Use
		– years –			– % –	
British Columbia	X	3.0	1.9	0	19	> 40
Alberta	X	4.4	2.7	0	4	24
Saskatchewan	X	X	3.7	0	0	11
Manitoba	X	X	3.5	0	0	13
Ontario	X	2.7	1.7	0	24	> 40
Quebec	X	X	X	0	0	0
Atlantic	X	X	X	0	0	0

X – a payback period of over 5 years

[1] Conversion cost (after tax and federal grant) of $900

[2] Based on a series of after-tax savings for 5 years

TABLE 5. PAYBACK PERIODS AND INTERNAL RATES OF RETURN FOR THE CONVERSION OF HEAVILY USED TRUCKS, PROVINCES AND ATLANTIC CANADA, 1986[1]

Province or Region	Payback Periods: Propane Price Scenario No. 1	Payback Periods: Propane Price Scenario No. 2	Payback Periods: Propane Price Scenario No. 3	Internal Rate of Return: Propane Price Scenario No. 1	Internal Rate of Return: Propane Price Scenario No. 2	Internal Rate of Return: Propane Price Scenario No. 3
		– years –			– % –	
British Columbia	1.6	1.9	2.5	> 40	> 40	28
Alberta	2.2	2.9	4.5	35	21	4
Saskatchewan	2.8	4.0	X	23	8	0
Manitoba	2.6	3.8	X	26	10	0
Ontario	1.4	1.6	1.9	> 40	> 40	> 40
Quebec	3.4	4.9	X	14	0	0
Atlantic	X	X	X	0	0	0

X – a payback period of over 5 years

[1] Conversion cost (after tax and federal grant) of $1200

and western Canada. However, if the high propane price scenario occurs, propane truck conversion would be attractive only in Ontario and British Columbia.

Conversion of Farm Machinery Assuming Excess Propane-Storage Capacity

The analysis considered the economics of a farm operator converting farm machinery that is used exclusively on the farm, assuming excess propane-storage capacity. In addition to the cost of conversion, the farm operator would incur the additional expense of a pumping device. In this analysis, it was assumed that a hand pump would be purchased, costing about $450. The analysis is based on converting both a gasoline tractor and a combine to propane use and assumes the consumption of 10 289 L a year.[5] The analysis is based on two vehicles being converted since, with the added capital cost of establishing a propane dispensing unit, it is unlikely that a farmer would convert only one vehicle.

The payback period and internal rate of return for the conversion of a gasoline tractor and combine entailing the additional expense of a purchased hand pump are illustrated in Table 6. The analysis indicates that some farm operators with excess propane-storage capacity will benefit by converting farm machinery. Internal rates of return of over 15% were calculated for most western provinces and for Ontario.

With the low and moderate propane-price scenario, conversions will be economically feasible in most regions of Canada. With the high propane-price scenario, they will, however, be attractive only in Ontario and possibly Alberta.

Conversions of Farm Machinery Assuming No Excess Propane Storage Capacity

A farm operator who does not use propane or have excess propane-storage capacity will have to purchase a propane storage tank in addition to the pumping device. The cost of a small storage tank (1900 L) and hand pump will be about $2500. The analysis was based on the conversion of a gasoline tractor and combine to propane use, assuming the consumption of 10 289 L a year.

The cost of a 1900 L propane dispensing unit and hand pump makes it uneconomical for farm operators without excess storage capacity to convert farm vehicles to propane use. For 1982, payback periods of over 4 years were calculated for all provinces, for the conversion of a gasoline combine and tractor. Even under the low-price scenario, the cost of a fuel-dispensing unit makes it uneconomical for farmers without excess propane-storage capacity to convert farm machinery to propane use, until at least 1986.

[5] Estimates of fuel use per vehicle were provided by Canadian Resourcecon Ltd. Fuel use was estimated to be 5659 L per farm tractor per year and 4630 L per combine per year.

TABLE 6. PAYBACK PERIODS AND INTERNAL RATES OF RETURN FOR THE CONVERSION OF A GASOLINE TRACTOR AND COMBINE TO PROPANE USE ASSUMING EXCESS PROPANE STORAGE CAPACITY

Province or Region	1982[1]		1986[2]					
			Payback Periods			Internal Rate of Return[3]		
	Payback Period	Internal Rate of Return	Propane Price Scenario No. 1	Propane Price Scenario No. 2	Propane Price Scenario No. 3	Propane Price Scenario No. 1	Propane Price Scenario No. 2	Propane Price Scenario No. 3
	– years –	– % –						
British Columbia	2.3	33	2.0	2.6	4.0	40	26	8
Alberta	2.6	26	2.0	2.7	4.1	40	25	7
Saskatchewan	3.5	13	2.6	3.7	X	26	12	0
Manitoba	3.1	17	2.4	3.3	X	31	15	0
Ontario	2.4	31	2.0	2.4	3.2	40	31	17
Quebec	3.4	14	2.6	3.3	X	27	15	0
Atlantic	4.3	5	3.8	X	X	10	0	0

X – payback period of over 5 years
[1] Conversion cost (after tax and federal grant) of $900 per vehicle. Assume a hand pump is purchased for $450.
[2] Conversion cost (after tax and federal grant) of $1200 per vehicle. Assume a hand pump is purchased for $550.
[3] Based on an after-tax savings for 5 years

IN REPLY TO AUTHORS AND EDITORS REGARDING VOL. 18, NO. 2.

CANADIAN FARM ECONOMICS

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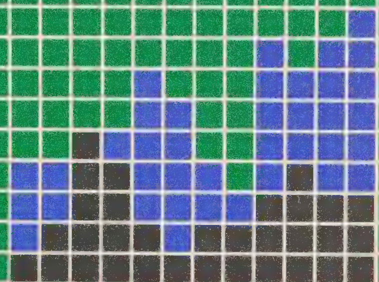
CANADIAN FARM ECONOMICS



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Contents

Agriculture Canada policy and expenditure patterns 1868-1983

D. Berthelet[1]

This article chronologically reviews the policies and expenditures of Agriculture Canada vis-à-vis the agri-food sector from its beginning in 1868 until 1983. The purpose of the article is to provide a better understanding of Agriculture Canada by describing its evolution over the past 115 years.

The discussion is not intended to provide a history of the department. It focuses on departmental policy development and related issues, and provides a correlation with the socioeconomic environment in each of the defined periods. The periods noted were selected on the basis of major national and global historic and/or economic events.

OVERVIEW

Graph 1, which gives an overall perspective of departmental policies and expenditures between 1868 and 1983, shows that Agriculture Canada policies generally followed the development of national policy. In the nation building period, 1868-1929, national policy was developmental in nature and was reflected in agricultural policies. During the 1930s, national policy was directed toward social concerns; the Department of Agriculture stressed farm assistance policies and programs. This trend continued until the beginning of World War II in 1939.

During World War II, agricultural policies were modified to serve the needs of the war. Livestock production became more important than grain output, and many programs and policies of the department were designed to encourage meat production. At the end of the war, the Keynesian doctrine provided the theoretical justification for government to intervene in the economy. This change was reflected in Department of Agriculture policies through increased involvement in marketing, and price stabilization activities directed to support farm income. During the late 1950s and the 1960s, expectations with respect to growth in the economy provided the basis for expansion in the Canadian social security system. At this time, transfer-oriented programs of the department grew rapidly, as shown in Graph 2. In the 1970s and the early 1980s, declining economic growth, inflation and high unemployment influenced national policy. Budget restraint became evident in national programs, and funding of new, high priority initiatives was undertaken increasingly at the expense of low priority programs. Since 1980-81, the impacts of scarcity and resource constraints have become evident within Agriculture Canada and real expenditures by the department have declined appreciably. Since that time there has been little change.

Graph 1 shows that the current profile of Agriculture Canada has evolved gradually. In the pre-1941-42 period, although expenditures had a slight tendency to increase, they remained steady and did not vary by large amounts from year-to-year. This in part reflected the disposition of government in the prewar era to avoid direct financial intervention in the economy.

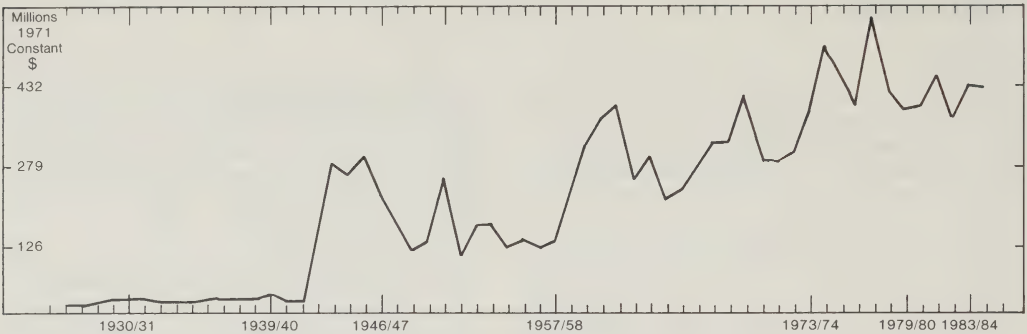
The expenditure pattern changed, however, after 1941-42. Departmental expenditures surged during the war to provide the subsidies and financial incentives necessary to redirect agriculture from grain towards livestock production to meet the demands of war. When peace was regained, some of the programs introduced during the war, such as feed freight assistance, farm loan guarantees and price supports, continued. A greater role in the economy was exercised by the department in the postwar period. Consequently, departmental expenditures did not revert to prewar levels.

Expenditure levels between 1948-49 and 1957-58 varied somewhat due to the Korean War, but they did not have an overall tendency to increase or decrease. However, after 1957-58, the department's expenditures grew in real terms. Graph 2 provides a detailed view of the situation from 1957-58 to 1983-84. Much of the increase in the department's expenditures was due to increases in direct transfers to producers. Graph 3 shows that during the 1957-58 to 1962-63 period, payments to the western grain industry accounted for most of the increase in departmental expenditures. Since 1962-63, however, expenditures by the Agricultural Stabilization Board, especially payments to the Canadian Dairy Commission, have accounted for a large part of the growth in departmental expenditures.

NATION BUILDING 1868-1929

At the time of Confederation in 1867, the provinces were geographically isolated. A major problem facing the federal government was linking the new provinces to create a second North American nation. Canada was a 'hard frontier', and the exploitation of her resources required large accumulations of capital and state support to make the vast western lands acquired from the Hudson Bay Company in 1870 accessible. The agricultural prospects of the Canadian west were uncertain at that time and remained so for a generation.[2] Until the later part of the century, competition for immigrants by other countries such as Australia, Argentina, Brazil and the United States rendered Canadian immigration efforts extremely disappointing.[3] In 1895, in spite of the railway development, the prairies remained virtually unsettled.

GRAPH 1 POLICY DEVELOPMENT AND EXPENDITURES



Nation Building (1867-1929)

National policy was directed at creating an industrial base in Ontario and Quebec, uniting the country from sea to sea by building the CPR, settling the West to develop its resources and to supply the Eastern industrial heartland, and to heaf off encroaching American interests

The overall direction of agricultural policy was expansionary. It consisted of promoting productivity, increasing efficiency, bringing people into agriculture via immigration, providing some credit, and allocating land to people who would engage in farming.

Depression and War (1930-1945)

The new idea that the federal government should take direct action to ensure all Canadians had an adequate and comparable level of social services gained support in the 1930s. Wartime policy included direct controls along with measures to stimulate and orient the economy to the needs of the war effort

Economic pressures of the 1930s introduced the concept that public policy had responsibility for agricultural income stability and expansion of productivity. During the wartime period, agriculture was used to support the war effort

Post-War Growth (1946-1956)

This period was characterized by strong optimism about Canada's growth. The Keynesian doctrine influenced national economic policy. Government assumed responsibility for economic stability.

Era of Social Program Development (1957-1972)

During this period, several major social initiatives were implemented. The period was characterized by the buoyant expectations of an expanding economy.

The major thrusts of agricultural policy: to expand output and increase productivity and efficiency; heavy involvement in marketing; and price stabilization for farm income stability. Major economic and social goals, especially since 1958, were to attain equitable distribution of farm income

Discovery of Scarcity (1973-1979)

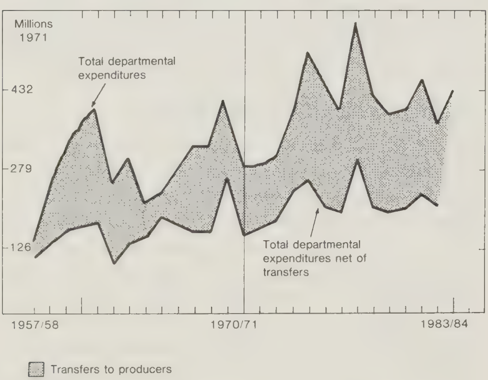
Scarcity (1980-1983)

As declining growth and high inflation rates exerted their influence, policy development and the allocation of government expenditures became difficult. Increasingly, gains for one group became a visible loss for another group, region, or sector.

Agricultural policy stressed the need to develop and expand Canada's production base and exports, and to ensure adequate supply of safe, nutritious food at reasonable and competitive prices.

The principal aims of the Agri-Food Strategy: to enhance export market opportunities; sustain and upgrade the natural resource base; expand research and technology transfer; assist in alleviating world food needs; and address public interests and policy issues

GRAPH 2 EXPENDITURES

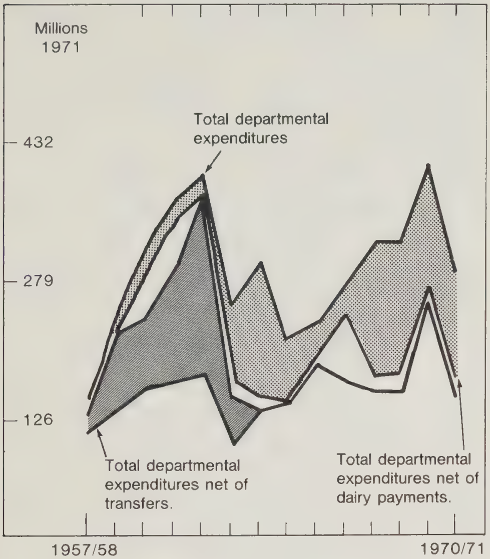


After the turn of the century, the vigorous immigration policy of Clifford Sifton, the then Minister of the Interior, resulted in filling the vacant spaces in the Canadian west[4] and made western Canadian farmers the most important farm group of the Canadian economy. The outstanding issues involved the monopoly position and associated trade practices of the CPR and the elevator companies. As a result, the first of a series of Royal Commissions to investigate the grain trade was appointed in 1899. Ultimately, the federal government introduced legislation to influence the grain trade in western Canada, such as the Manitoba Grain Act of 1900 and the Canada Grain Act of 1912. This legislation introduced a Board of Grain Commissioners — later to become the Canadian Grain Commission — which oversaw the grain trade in the west.

By the beginning of World War I, all but a small part of the arable land in Canada was under cultivation. By the end of the war, the Canadian trade union movement had grown rapidly and Canada had begun to develop an industrial profile. The emphasis of economic development shifted to the 'new industrialism' based on minerals, pulp and paper, and hydroelectricity. The major objective of federal agricultural policy began to move away from expansion and towards sheltering the industry from the vagaries of world prices.[5]

The economic milieu of the period expanded Agriculture's activities. They included research with the passage of the Experimental Farm Station Act in 1886, and extended to matters such as settlement and opening of the west, e.g. allocating land to people who would engage in farming. National policy at this time aimed to create an

GRAPH 3 EXPENDITURES



Dairy Payments Agriculture Stabilization Board and Canadian Dairy Commission.

Agriculture Stabilization Board less dairy payments.

Payments to the Western Grain Industry direct payments to western grain producers, carrying cost of Canadian Wheat Board wheat, and Prairie Farm Emergency Fund.

industrial base in Ontario and Quebec under protective tariffs, unite the country from sea to sea by building the Canadian Pacific Railway, settle and develop the west, and stop American interests anxious to exploit the Canadian frontier.[6] Until 1906, the Department of Agriculture was responsible for immigration and emigration, as well as for the Marine and Immigrant Hospital in Quebec. Until 1927, the department was also responsible for public health and quarantine, the census, statistics and registration of statistics, patents of invention, and copyrights.

Over the 1868-1929 period, the overall objective of agricultural policy was development. This policy included making farm loans to improve competition in farm mortgages, encouraging the development of cooperatives, tightening of rules governing the grain trade, engaging in agricultural research and promoting exports.[7] Agriculture remained to a large extent a classically competitive industry. Strictly limited intervention in the economy characterized the government's attitude towards income and welfare; consequently farmers were left to devise solutions to their problems through cooperatives. The exception, however, was the western grain trade and the previously mentioned monopoly position and associated trade practices of the CPR and grain elevator companies.

Until the turn of the century, immigration and agricultural expansion in western Canada was poor. Part of the federal government's agricultural problem involved demonstrating the agricultural possibilities of the west, and to a large extent the founding and expansion of the dominion experimental farm system was intended to support agricultural development in western Canada.

Some of the more important events that took place during the 1868-1929 period were:

1886	The Experimental Farm Station Act established the experimental farm system to conduct investigative work to develop improved plant and animal varieties best suited to different parts of Canada.
1890	Dairy Branch was established to develop and distribute information on the best methods of making butter and cheese and feeding cattle for milk production.
1897	The Crow's Nest Act enabled the federal government to provide for the construction of a rail line through the Crow's Nest Pass subject to a reduction in freight rates.
1900	The Manitoba Grain Act made it possible for farmers to sell their grain "on track" or to consign it to commission men. It required grain dealers to be licensed, and made the grain trade more competitive.
1912	The Canada Grains Act provided rigorous government supervision of the grain trade and provided a board of grain commissioners, now the Canadian Grain Commission.
1917	The Board of Grain Supervisors was given the power to fix a uniform price of wheat. The Board was terminated in 1919.
1919	The Canadian Wheat Board operated a compulsory wheat pool for a year and then was disbanded.
1925	The Crow's Nest Pass Rates became statutory to ensure uniform transportation rates for western grain shipments for export.
1927	The Canadian Farm Loans Act ensured long-term mortgage funds were available to farmers at competitive interest rates. It was replaced in 1959 by the Farm Credit Act which created the Farm Credit Corporation.

Before the turn of the century, agriculture in Canada approached a cottage industry that provided little more than subsistence incomes. Although farmers complained of low produce prices, little was done on their behalf other than, for example, assistance in the international marketing of some commodities and in the establishment of dairies in areas where none existed. Around the turn of the century, the monopoly positions of the CPR and elevator companies in western Canada forced government to regulate the grain trade: the Crow's Nest Pass agreement was negotiated in 1897; the Manitoba Grain Act was enacted in

1900; and the Canada Grains Act was passed in 1912. By the beginning of World War I, policy shifted to protecting farmers from commodity price variability, and by 1927 agricultural policy was extended to ensure the availability of long-term credit to farmers at favorable interest rates.

In review, agricultural policy over the 1868-1929 period evolved from an expansionary theme of opening the west (e.g. allocating land to settlers and demonstrating the agricultural possibilities of the prairies) to protecting producers from abuses of monopoly, the uncertainties of world commodity prices, and high interest rates in credit markets.

DEPRESSION AND WORLD WAR II 1930-1945

The Depression of the 1930s was centered in the United States where it lasted the longest and had the most severe effects. The Depression revealed Canada's vulnerability to foreign economic influences such as low world commodity prices and market protectionism. Moreover, government had not developed methods to deal with the effects of reduced economic activity. Neither macroeconomic stabilization nor social intervention were considered the responsibility of government.

During the Depression, public opinion concentrated on economic disparities and the associated human suffering. The concept that the federal government should reduce inequities gained support; however, the concept was too radical to gain government support during the 1930s.[8] Not until World War II did macroeconomic stabilization become accepted as a role of government, and although unemployment insurance had been introduced in 1940, it was not until the 1960s that significant social policies were implemented.

During the 1930s, agriculture suffered direct effects of the Depression, such as surplus markets and low commodity prices which created serious financial problems for farmers. Moreover, successive years of drought and crop failure in the west intensified the plight of the sector. Price and crop conditions combined to reduce net income from farming operations to negative amounts in Manitoba in 1931, and in Saskatchewan between 1931 and 1934.[9] The economic hardships of the period forced government to widen its agricultural policies to provide assistance and price maintenance, but stopped short of significant direct financial support to farmers.

Both Ottawa and the provinces acted in the 1930s to set up producer marketing boards, but initial efforts were turned back by the courts. British Columbia passed a Produce Marketing Act to set up marketing boards for certain fruits and vegetables, but this was ruled unconstitutional by the Supreme Court of Canada in 1931 on the grounds that it affected interprovincial trade and that the levy on producers was an indirect tax. The federal National Farm Products Marketing Act of 1934 tried to establish a system of national marketing boards, but it was ruled unconstitutional on the grounds that it interfered with provincial powers.[10]

Departmental activities of the 1930s are reflected in some of the more important events that took place during that period:

1934 The Farmers Creditors' Arrangements Act permitted farmers' debt service payments to be adjusted to the ability to pay.

1934 The National Farm Products Marketing Act provided for federal marketing boards which could delegate powers to local producer boards to control the sale of products and to levy equalization payments on producers and processors. It was declared *ultra vires* in 1935.

1935 The Canadian Wheat Board which provided a minimum guaranteed price for wheat was established. Producers were given the choice to sell to the Board or on the open market.

1935 The Prairie Farm Rehabilitation Act dealt with the immediate problems of drought and depression on the prairies.

1939 The Prairie Farm Assistance Act provided financial assistance to farmers who experienced crop failure.

1939 The Agriculture Products Cooperatives Marketing Act facilitated orderly marketing through cooperatives.

During the 1930s, the economic condition of farmers became of concern and the concept of public policy responsibility for agricultural income support and stability emerged.[11] However, this was not exhibited in the expenditure profile of the department. During the Depression of the 1930s, which essentially lasted until the beginning of World War II,[12] departmental expenditures did not increase to compensate for, or to alleviate in a significant manner, the economic difficulties felt by farmers. This is illustrated in both Graph 1 and Table 1.

During the World War II, agricultural policy concentrated on promoting national interests by controlling agricultural prices and production, and encouraging output of products necessary for the war. These objectives were carried out through a blend of controls and incentives. For example, when the war broke out in 1939 a surplus of wheat caused depressed prices. As the war spread, wheat markets were lost, resulting in financial problems for western grain producers. Remedial actions extended to instituting a grain quota delivery system, reduced wheat acreage, and controlled wheat prices. It was not until 1942 that farm income surged, doubling that of prewar levels, to reflect increased wartime economic activity and government production incentives. Some of the more important events during the period were:

1941 The Wheat Acreage Reduction Act reduced the wheat surplus that persisted during the first year-and-a-half of the war.

1941 The feed freight assistance program encouraged livestock production in eastern Canada and in British Columbia to meet the increased demand due to the war.

1941 Feed grain storage subsidies encouraged early purchase of feed grain supplies by eastern farmers.

1941 Fertilizer subsidies encouraged crops important to the war effort.

1943 The Canadian Wheat Board Act was expanded to give the board exclusive powers in the international marketing of wheat, wheat produced for food, including industrial purposes, and international feed wheat trade.

1944 The Agricultural Prices Support Act stabilized prices received by farmers. It was replaced in 1958 by the Agricultural Stabilization Act.

1944 The Farm Improvement Loans Act provided loan guarantees for farmers. It protected producers from serious financial short-run losses due to market fluctuations. The program is continuing.

1944 The Export Credit Insurance Act gave loan loss protection against extending credit to foreigners. In 1968, the Act became incorporated into the Export Development Corporation Act.

During World War II, real expenditures by the department grew rapidly from $23.6 million in 1941-42 to $270.5 million in 1945-46 (see Table 1). This surge in expenditures, as shown in Graph 1, represented an 11.5 fold increase in departmental expenditures over the 4-year period. Pressures of the war provided the justification by which the government systematically intervened in the agri-food economy to provide financial incentives and subsidies to orient agriculture to wartime production. With the emergence of peace, departmental expenditures declined somewhat, reflecting amongst other things a reduced need for government financial activity in the industry. Expenditures did not decline, however, to prewar levels because some of the programs, such as feed freight assistance and commodity price stabilization, initiated during the war continued.

POSTWAR GROWTH 1946-1956

The emerging Keynesian doctrine professed to enable governments to fine-tune the economy without significant expansion of public ownership or widening wartime controls. It helped to validate macroeconomic intervention in the postwar period. Interventionist sentiment was assisted by left-wing political pressures and by prewar and wartime public enterprise. Consequently, the federal government maintained a higher profile in the economy after the war. Some of the stated national policy objectives were full employment, a high rate of economic growth, price stability, viable balance of payments, and equitable distribution of income.

Agricultural policy after the war was commodity-oriented with emphasis on expansion, marketing, and price stabilization. Much of the new legislation introduced over the 1946-47 to 1956-57 period was market-oriented.

1947 The Canadian Wheat Board Act was amended to continue the exclusive wheat marketing powers of the Board in Manitoba, Saskatchewan, Alberta and the Peace River region of British Columbia.

1948 The Canadian Wheat Board Act was expanded to include barley and oats.

1949 The Agriculture Products Marketing Act enabled the federal government to delegate interprovincial and export trade powers to provincial farm marketing boards.

1951 The Agriculture Products Board Act permitted the Board to buy, sell, process, and store agricultural products to stabilize market prices.

1952 The Canadian Dairy Products Act established dairy product standards.

1955 The Agriculture Products Standards Act established grades and standards for international and interprovincial trade in agricultural products.

After World War II, expenditures by the department did not fall to prewar levels. This pattern, in part, reflected the fact that expansion during World War II was used to provide more services to the sector, such as feed freight assistance, commodity price stabilization, farm loan guarantees, and marketing support.

After the war, agriculture income was unstable but remained buoyant until it peaked in 1951; however, it fell to less than one-half this amount by 1954. Over the 10-year period 1946-47 to 1956-57, the Canadian gross national product in real terms nearly tripled. However, with the exception of the Korean War period, departmental expenditures remained steady, indicating that they did not keep pace with the economy as a whole.

TABLE 1 EXPENDITURES 1971 CONSTANT $

Year	$ (million)	Year	$ (million)	Year	$ (million)	Year	$ (million)
1926-27	18.3	1941-42	23.6	1956-57	125.6	1970-71	285.9
1927-28	20.7	1942-43	156.7	1957-58	137.6	1971-72	286.1
1928-29	22.6	1943-44	285.8	1958-59	237.6	1972-73	298.0
1929-30	28.2	1944-45	262.9	1959-60	319.4	1973-74	376.2
1930-31	28.6	1945-46	270.5	1960-61	367.1	1974-75	506.8
1931-32	30.8	1946-47	227.4	1961-62	396.0	1975-76	445.0
1932-33	26.8	1947-48	174.2	1962-63	249.9	1976-77	392.9
1933-34	23.6	1948-49	120.4	1963-64	301.7	1977-78	556.3
1934-35	23.7	1949-50	140.3	1964-65	216.4	1978-79	417.7
1935-36	31.2	1950-51	260.6	1965-66	235.5	1979-80	385.7
1936-37	28.1	1951-52	110.1	1966-67	279.2	1980-81	391.4
1937-38	28.3	1952-53	167.5	1967-68	321.8	1981-82	451.5
1938-39	29.9	1953-54	170.4	1968-69	323.4	1982-83	368.4
1939-40	37.4	1954-55	126.6	1969-70	414.5	1983-84	433.1
1940-41	26.0	1955-56	135.7			1984-85	426.4[1]

[1] Estimate

Source: Public accounts, various issues

ERA OF SOCIAL PROGRAM DEVELOPMENT 1957-1972

By the mid-1950s, technology and industrialization had not only created a generally affluent society, but had also altered the role of government in society. Government increasingly assumed an active role in the socioeconomic environment. Industrialization in Canada created labor-industry problems and new social norms and values, with the result that traditional agencies were no longer able to reconcile labor demands nor to continue carrying the burden of welfare. Growing pressures forced the government to enter the field of labor-industry relations and to redistribute income through major social programs.[13]

The 1957-1972 period was distinguished by promising expectations about Canada's future. There was broad agreement in Canadian society that government should act to solve the major social and economic problems, and that more government was an acceptable price for the services provided by its programs. During this period, Canada enjoyed a surplus in its merchandise trade account. The Soviet Union became an important purchaser of Canadian grain and the U.S. dollar traded between $0.959 and $1.079 Canadian. The federal government implemented many of its current social programs such as the Canada Pension Plan, Medicare, Old Age Security, Canada Assistance Plan for assistance to higher education, and manpower training. In the late 1960s and early 1970s, the federal government became more sensitive to regional needs. As a result, equalization payments increased rapidly. The Department of Regional and Economic Expansion was created in 1969 to provide industrial incentives, infrastructure assistance, and social assistance to the regions, and to ensure equitable development across Canada.

Between 1957 and 1972, farm income fluctuated widely from year-to-year and, as shown in Table 1, between 1957-58 and 1972-73 departmental expenditures more than doubled from $137.6 million to $298 million. This increase reflected a major shift in departmental expenditures towards transfers to producers. This increase in transfer payments can be seen in Graph 2. Between 1957-58 and 1972-73 (see column 9 of Table 2), transfers to producers, in constant dollars, increased three-and-one-half times from $33.4 million to $117.9 million. Federal policy with respect to agricultural income and prices was carried out primarily by providing price support to farmers. The objective was to reduce production and price risks to farmers and to provide a fair and stable farm income.[14]

In 1972, Parliament passed the Farm Products Marketing Agencies Act, which permitted the provinces and Ottawa to work together to form national farm marketing boards. Since then, national marketing boards have been formed for eggs, turkeys, and chickens. Today, about 55-60% of farm cash income is earned through marketing boards, with the products controlled ranging from poultry, eggs, honey, and hogs, to milk, fruit, grains, tobacco, soybeans and maple syrup.[15]

Some significant events of the 1957-58 to 1970-71 period show the shift in departmental emphasis to income protection:

1958	The Agriculture Stabilization Act named nine commodities whose prices should be held at a prescribed minimum level.
1959	The Crop Insurance Act provided protection against crop failure.
1959	The Farm Credit Act encouraged the reorganization of farms into economic family units.
1958-61	Direct subsidies were provided to grain producers.

TABLE 2 EXPENDITURES[1] 1971 CONSTANT $ (MILLION)

	Payments to the western grain industry				Agriculture Stabilization Board			Crop Insurance	Transfer to producers
	Prairie farm emergency funds	Payments to grain producers	CWB grain carrying charges	Total (4)	Dairy (CDC)	Non-dairy payments	Total		Total (9)
YEAR	(1)	(1)	(3)	(1+2+3=4)	(5)	(6)	(5+6=7)	(8)	(4+7+9=9)
1957-58	24.7	—	—	24.7	NA	NA	8.7	—	33.4
1958-59	24.3	59.2	—	83.5	11.5	10.2	21.7	—	105.2
1959-60	17.6	—	59.5	77.1	30.2	54.4	84.6	0.01	161.7
1960-61	12.8	56.2	66.8	135.8	19.6	50.8	70.4	0.2	206.4
1961-62	65.9	55.3	67.4	188.6	21.6	8.8	30.4	0.3	219.3
1962-63	9.9	—	48.0	57.9	81.3	16.6	97.9	0.5	156.3
1963-64	1.4	—	—	1.4	154.2	12.6	166.8	0.6	168.8
1964-65	0.6	—	—	.6	70.4	2.6	73.0	0.7	74.3
1965-66	—	—	—	—	39.3	8.9	48.2	0.9	49.1
1966-67	—	—	—	—	37.4	69.9	107.3	1.6	108.9
1967-68	—	—	—	—	148.4	16.0	164.4	2.9	167.3
1968-69	—	—	—	—	152.0	10.3	162.3	5.5	167.8
1969-70	—	—	—	—	142.4	4.8	147.2	5.0	152.2
1970-71	—	—	—	—	129.0	1.4	130.4	3.9	134.3
1971-72	—	—	—	—	107.0	15.0	122.0	4.0	126.0
1972-73	—	—	—	—	102.3	10.6	112.9	5.0	117.9
1973-74	—	—	—	—	125.1	0.1	125.2	14.5	139.7
1974-75	—	—	—	—	190.1	35.2	225.3	23.6	248.9
1975-76	—	—	—	—	188.0	17.6	205.6	33.0	238.6
1976-77	—	—	—	—	145.3	18.0	163.3	35.2	198.5
1977-78	—	—	—	—	170.4	40.9	211.3	42.3	253.6
1978-79	—	—	—	—	147.7	25.6	173.3	40.8	214.1
1979-80	—	—	—	—	138.0	15.0	153.0	38.5	191.5
1980-81	—	—	—	—	129.4	21.5	150.9	44.5	195.4
1981-82	—	—	—	—	121.7	54.4	175.8	46.5	222.7
1982-83	—	—	—	—	107.1	2.2	109.8	51.8	161.6
1983-84	—	—	—	—	119.6	28.7	148.3	46.1	194.4

[1] Does not include administration costs

Sources: • Public accounts
• Agriculture Stabilization Board Schedule of Payments
• Annual Report of the Minister under the Crop Insurance Act

1961 The Agriculture Rehabilitation and Development Act was instituted to relieve rural poverty.

1966 The Canadian Dairy Commission Act provided efficient producers of milk and cream the opportunity of obtaining a fair return for their labor and investment and provided consumers of dairy products with a continuous and adequate supply of dairy products of high quality.

1970 The Lower Inventory for Tomorrow (LIFT) program was implemented to reduce the amount of wheat in storage by one-half. The program featured acreage reduction payments.

1972 The Farm Products Marketing Agencies Act permitted the provinces and the federal government to establish national farm marketing agencies and boards.

1972 The Small Farm Development program helped farmers by providing farm management counseling and a land transfer plan. The land transfer plan assisted those who wished to sell their land to retire or to take advantage of other job opportunities. It also helped farmers to purchase additional land. It was discontinued in 1979.

Transfers to producers were generally commodity oriented. Programs such as crop insurance and price stabilization were based on producers' need for protection against crop failure and unreasonably low prices for farm produce which results from chronic instability inherent in agriculture commodity markets. In the 1957-58 to 1962-63 period, due to the economic recession, the western grain industry suffered an economic slump. Subsidies were paid directly to producers (see columns 2 and 3 of Table 2 for specific information). Payments were also made to the Canadian Wheat Board for carrying costs of stored wheat.

Payments to the western grain industry averaged $94.6 million per year for the 6-year period 1957-58 to 1962-63, and accounted for the greater part of transfers to producers.

From column seven in Table 2, it can be seen that between 1957-58 and 1972-73 commodity price stabilization payments grew 13 times from $8.7 million to $130.4 million. About 80% of the payments made by the Agriculture Stabilization Board during this period were to the dairy industry through the Canadian Dairy Commission.

In summary, during the 1957-58 to 1972-73 period, Canada's overall economic prospects were perceived to be excellent and more government intervention was believed to be the most appropriate means of dealing with Canada's social and economic issues. The period can be described as that during which the Department of Agriculture began to assume a more pronounced role in direct transfer payments to producers.

DISCOVERY OF SCARCITY 1973-1979

The early 1970s were buoyant, characterized by high economic growth, low unemployment and low inflation rates. However, the buoyant outlook changed as the Canadian economy began to experience "stagflation" apparently caused by the first OPEC oil crisis of 1973 and accentuated by the second OPEC oil crisis of 1978-79. During this period, the major banks increased their international presence, and the Bretton Woods Agreement fixed-exchange-rate system broke down. In 1977, for the first time in one-and-a-half decades, the Canadian dollar lost its relative parity with the U.S. dollar, falling to a 45-year low of below $0.89 U.S., and closing at $0.84 U.S. in December 1978. The facade of a 'special relationship' between Canada and the U.S. began to crack in the 1970s,[16] and Canada's worsening economic circumstances resulted in the government's pursuit of an 'industrial strategy'.

Keynesianism had been the dominant government policy model until the mid-to late 1970s. The increasing inability of demand management to fine-tune the economy resulted in growing disillusionment with the approach, and monetarism emerged as a strong policy option.

During this period, especially after 1974, deficits became an intractable problem. The growing deficits reflected relative stability in expenditures and a decline in government revenues.[17] Within government, resource allocation became more difficult. The expenditure plan for the 1976-77 fiscal year called for expenditure cuts of $1.5 billion, limited public sector growth to 1.5%, suspended indexing of Family Allowances for one year, froze the DREE budget, canceled indexation on all manpower training programs and discontinued the activities of Information Canada. Restraint became an underlying theme within government as shown by the staffing cuts announced for many departments in the fall of 1978.

Graph 4 shows that in 1977-78, departmental expenditures, in terms of 1971 constant dollars, peaked, and since that time have remained roughly static in real terms. This was in part due to a decline in transfers to producers, and in particular to a decline in payments to the Canadian Dairy Commission. Over the period, agricultural income was highly variable. Between 1971 and 1973 it increased by 80%; it peaked in 1975 and fell by 44% by 1977.

In 1977, 'A Food Strategy for Canada' was announced jointly by the Ministers of Agriculture and Consumer and Corporate Affairs which expanded the scope of agricultural policy. For several decades agricultural policy was essentially synonymous with farm policy. After this announcement, agricultural policy increasingly encompassed the broader concept of agri-food policy.

Some significant departmental events in the 1972-73 to 1978-79 period were:

1973 The Crop Insurance Act amended the federal cost-sharing provision, resulting in greater farmer participation in the program, and larger federal contributions.

1974 The New Feed Grain Policy was implemented to ensure adequate supplies of domestic feed grains at prices fair to grain producers and livestock feeders throughout the country.

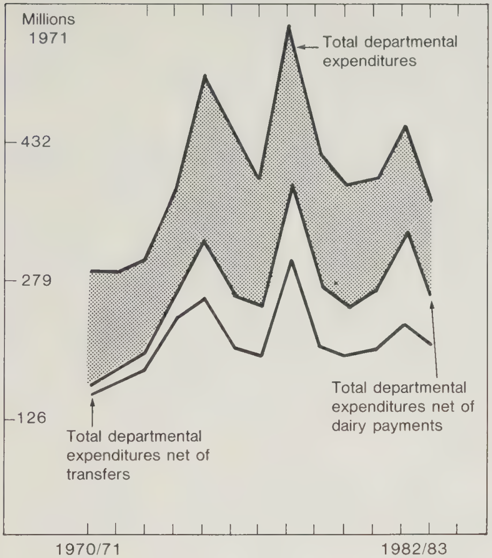
1975 The Agriculture Stabilization Act was amended to ensure more effective protection for producers. It changed the list of "named" commodities and altered the stabilization formula to more closely reflect current market prices and costs.

1976 The Western Grain Stabilization Act was established to provide income stability to western grain farmers. The Act established a fund based on contributions from producers and the federal government. Producers received payments when receipts adjusted for costs in the prairie region fell below a 5-year adjusted average.

1977 A Food Strategy for Canada announced jointly by the Ministers of Agriculture and Consumer and Corporate Affairs stressed the need to expand Canada's productive and export strengths to ensure an adequate supply of safe, nutritious food at reasonable and competitive prices.

The policies of the Canadian government moved increasingly towards fiscal restraint on government spending. During this period, the government's Anti-Inflation and Emergency Supply programs were announced. Agriculture Canada policies began to reflect restraint. Not only had the magnitude of transfers to producers changed, but also their composition. From 1977-78, transfers to producers were reduced, and greater reliance was placed on

GRAPH 4 EXPENDITURES



Dairy Payments Agriculture Stabilization Board and Canadian Dairy Commission.

Agriculture Stabilization Board payments other than dairy payments.

crop insurance and stabilization payments to protect producers against risks due to market fluctuations and the vagaries of weather. During this period, the department began to expand its horizon to include the broader concept of agri-food policy and increased emphasis on food processing, distribution and retailing.

SCARCITY 1980-1983

Growing government deficits precipitated the need for greater restraint and control of government spending. The new Policy Expenditure Management System (PEMS) was implemented in December 1979, which strengthened the committee system for policy decision-making and introduced the envelope system for resource allocation. An important feature was the focus on trade-offs and policy alternatives to improve cost-effectiveness and to provide a mechanism to reduce expenditures. However, expenditures, the deficit and the public debt continued to grow.

In the late 1970s and early 1980s, the concept of the 'megaproject' emerged as a government economic development strategy. During this period, the National Energy Policy was introduced. The megaproject strategy envisioned several dozen major projects coming 'on-stream' in the late 1980s and early 1990s to provide the needed boost to the Canadian economy. This economic strategy lost its viability during the global economic recession of the early 1980s which resulted in a world oil surplus and precipitated the world debt crisis. During the recession, Canadian farm income fell markedly. In 1983, it fell to about one-half of what it had been in 1981. The growing deficit and the public debt became increasingly problematic. The government announced that "about half the deficit may be structural in nature and thus could not be expected to be eliminated automatically as the economy recovered".[18] In 1981, Agriculture Canada announced the Agri-Food Strategy to outline "the range and type of support activities required during the 1980s if the food and agriculture sector was to maximize its contribution to growth and development to the Canadian economy".[19] The strategy, which called for expenditures of $1.3 billion dollars over the 5-year period beginning in 1982-83, received Cabinet approval in 1981 'in principle' and without funding. Since that time, few of the initiatives under the strategy have been initiated due to the severe resource constraints prevailing in government.

Some of the significant developments in the 1979-83 period are as follows:

1979	A policy on privatization, contracting-out and cost recovery was announced.
1980	Agriculture Canada reorganized creating Food Production and Inspection Branch, Marketing and Economics Branch, and Regional Development Branch. A regional development committee was appointed in each province.
1981	The Agri-Food Strategy was announced to enhance market opportunities, sustain and upgrade the natural resource base, expand research and technology transfer, assist and alleviate world food needs, and address public interest and policy issues.
1981	A Treasury Board directive introduced cost recovery as government policy.
1981	The Ministry of State for Economic Development conducted an X-budget aimed at reducing by 5% the A-budget of the Economic Development Envelope departments. Agriculture Canada proposed cost recovery rather than program cuts.
1982	A mini-budget was proposed by the Minister of Finance which outlined the government's 6 and 5% restraint program.

1982 The Ministry of State for Economic Development stated that cost recovery should be considered a general financial objective of the government.

1983 Canadian Agriculture Export Corporation (Canagrex) came into existence to promote, facilitate and engage in the export of agricultural and food products from Canada. It was subsequently terminated March 31, 1985.

1983 The Government Reorganization Act was instituted. Prairie Farm Rehabilitation Administration was transferred to Agriculture Canada from the Department of Regional Economic Expansion. Regional Development Branch acquired the responsibility to negotiate regional development subagreements, a function which until that time was conducted by the former Department of Regional Economic Expansion.

The resource constraints experienced by the department since 1979-80 have affected the manner in which it conducts its affairs. For example, inspectors now use statistical sampling methods wherever possible, and inspection and grading services to industry are now conducted on a partial cost recovery basis.

The department has also changed its regional structure. In 1980 the Regional Development Branch was created along with an agricultural development committee in each province resulting in an increase in the department's regional activities. In addition, in 1983 the department was assigned the responsibility to negotiate the agricultural subagreements under the Economic and Regional Development Agreements (ERDAs).

In summary, over the 1978-79 to 1983-84 period, a depressed economy and growing government spending deficits imposed resource constraints on Agriculture Canada. The department reduced its real level of expenditures, curtailed growth in transfers to producers, and increased its regional sensitivity by assuming additional responsibilities for agricultural development in the regions.

CONCLUDING COMMENTS

In review, the policies of the Department of Agriculture reflected agricultural concerns, national policy and social-economic factors as they evolved. In the first four decades after Confederation, the orientation of government policy was nation building, and agriculture was used as a means of developing the country. In 1868, the Department of Agriculture was created and its mandate extended to industrial designs, trademarks, copyright, patent of inventions, the census, statistics, public health, quarantine, immigration and emigration. The policies of the department helped secure Canada's claim to the west, e.g. it encouraged settlement and allocated land to people who would engage in farming.

At the turn of the twentieth century, Canada's hold on the west was secure. The department lost its immigration responsibilities, and its policies began to stress development. As well, the experimental farm system grew rapidly during this period. Government agricultural policy broadened to address some concerns of farmers, e.g. it oversaw the grain trade in the west.

By the end of World War I, both national and agricultural policy had succeeded—Canada had developed an industrial profile, and most of the arable land was occupied. In the mid-1920s, the department lost its non-agricultural mandate, and government policy extended to more active support for farmers, e.g. statutory freight rates for western grain shipments were introduced and some long-term credit was provided to farmers. Agriculture policy during the Depression attempted to alleviate the economic hardships that farmers experienced — the Canadian Wheat Board was started, and marketing board legislation was introduced. However, government policy stopped short of significant direct financial assistance to farmers.

Agriculture during World War II supported the nation's war effort. It consisted of price and production controls including subsidies and incentives to direct agriculture production in support of the war effort. Keynesianism provided the basis for government to assume a role in managing the economy, and many of the wartime agricultural programs were continued after the war. The major themes of postwar agriculture policy: to expand output and increase productivity and efficiency, heavy involvement in marketing, and commodity price stabilization for farm income stability.

A generally buoyant Canadian economy in the postwar period continued through the 1960s when most of Canada's current social security programs were introduced. During the 1960s, farmers experienced wide year-to-year variations in their incomes. The chronic instability of agricultural commodity markets resulted in government making a more extensive commitment to farmers, and transfer payments to stabilize farm income became an important element in departmental expenditures.

In the 1970s, intractable economic problems of declining growth rates, double digit inflation, high unemployment and increasing government spending deficits developed. Departmental policy concentrated on expanding productivity and exports, and enlarged to encompass the broader concept of food policy. By the late 1970s and early 1980s, restraint in government became increasingly evident. Departmental policy stressed marketing, the natural resource base, and research; however, many proposed agricultural policy initiatives, though approved in principle, remained unfunded.

In 1977-78, in real terms, departmental expenditures peaked. Since that time they have declined to about the level they were in 1973-74, and have remained steady with no pronounced tendency to increase or decrease.

This brief historical overview of the evolution of Agriculture Canada in terms of policy and expenditures from its beginning in 1868 to the present indicates that it is a dynamic department adjusting to the changing needs of the times. Its policies have reflected national policies, and its resource utilization has reflected the changes in the economy and sectoral needs while maintaining efficiency and providing an acceptable level of services to its clients. The internal organization has indicated that the department is continuously adjusting to meet the challenges and opportunities as they emerge. However, growing financial constraints have reduced the departmental budget significantly in real terms, although it has grown in current dollars. Further reductions in resources may necessitate additional internal adjustments.

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[1] David Berthelet is an economist with Corporate Planning, Strategic Planning Division, Agriculture Canada. He would like to acknowledge the valuable comments and direction received from P. Cooper, B. Davey, C. Fulton, J. Groenewegen, Z. Hassan, D. Loken, J. McKenzie and F. Taylor, and especially Dr. D. Hedley and Mr. I. Singhal.

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Fiscal framework and agricultural expenditures in Canada

I. Singhal[1]

INTRODUCTION

The recent recessions in Canada have caused all-time highs in unemployment, inflation and interest rates, while economic growth has remained marginal. Despite the current upturn in the economy, the private sector has continued to be cautious towards investments. As a result, government revenues have dropped and the public debt has continued to increase. The government is facing the dilemma of a shortage of resources for economic expansion while being committed to reducing the deficit. Faced with rising costs, a large public debt, marginal increases in revenue, and public pressure to continue social programs, the government is likely to generate new money through cutbacks in low-priority, non-statutory programs. Other alternatives will be to raise taxes, further recover the cost of government services and/or continue deficit financing.

This article examines departmental expenditures and funding issues in relation to the national economic situation, the fiscal framework and the government Policy and Expenditure Management System (PEMS) which has been in place for the past several years. The purpose is to provide an overview of the past performance of Agriculture Canada, its current status and a brief outlook for the future. The expenditure patterns in the government and the department, as related to the agri-food sector, are examined in order to understand priorities and future directions. While on the surface this may seem to be a simple task, it is exceedingly complex since only about half of the total federal expenditure in the agri-food sector is carried out by Agriculture Canada. In addition, it is extremely difficult to determine the total expenditures by the provinces and the private sector.

The article begins with a review of total expenditures in the federal government, then considers expenditure patterns within each specific area (called "envelopes") in PEMS, and in the economic and regional development envelope in particular. It also reviews expenditures on the agri-food sector by Agriculture Canada and other federal departments and the provinces. The term "A-Base" has been used to describe the departmental allocations approved in the Main Estimates at the beginning of each fiscal year.

Over the past years, Agriculture Canada's A-Base has increased, but the growth rate has been below that of government expenditures. Yet the department has continued to provide the usual level of services. If this situation is continued, in the long run, departmental services to the agri-food sector and the public will deteriorate. This could have an adverse impact on sector performance due to a slowdown in research technology, transfer and other long lead time projects. Various aspects of regional development, such as job creation, resource conservation, and federal-provincial coordination are briefly noted. Agricultural trade is also discussed to show the relative position of and contribution by the agri-food sector to the balance of trade.

The data used in this article are gathered from a variety of sources. It was not possible to get relevant data consistently for the same periods. Consequently, the time periods and the base years are not identical throughout. In order to take into account the changes, growth is calculated on a compound basis over the period under review, although in some instances simple averages are also used.

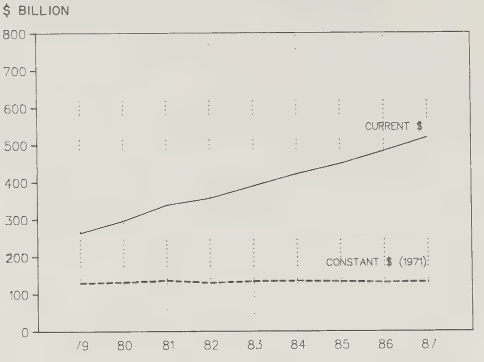
This article was prepared just prior to the 1984 federal election. Since then, changes in the government have occurred and new data have been generated. Although an effort has been made to update the article as much as possible, it should be noted that all recent changes could not be incorporated at this time. The impact of the merger of Forestry and the Grains group with Agriculture Canada has not been taken into account.

FEDERAL REVENUES AND EXPENDITURES

Over the 5-year period (1979-83), the Gross National Product (GNP) increased by 47%; however, in terms of constant dollars (1971), the average real growth in GNP during this period was less than 1%. Between 1984 and 1987, the projected growth in GNP is expected to be over 29% and the real growth is expected to remain marginal at an average of about 1.5% per year. This trend, as shown in Figure 1, will have an impact on government revenue and expenditures.

In the same period (1978-79 to 1983-84), federal expenditures increased from $52 billion to $91 billion, a growth of 75%, which is far in excess of the 47% growth in GNP. In 1983-84, federal expenditures were over 23% of GNP. For the 4-year period 1984-85 to 1987-88, federal expenditures as projected in the fiscal plan of February 1984 will grow from $98 billion to $115 billion, an increase of over 17%. This is considerably less than the expected growth of 29% in GNP over the same period. By 1987, government expenditures are expected to drop to about 20% of GNP. This indicates that over the next 4 years, the federal government will be reducing its share of GNP, leaving a relatively larger portion to the private sector.

FIGURE 1 GROSS NATIONAL PRODUCT

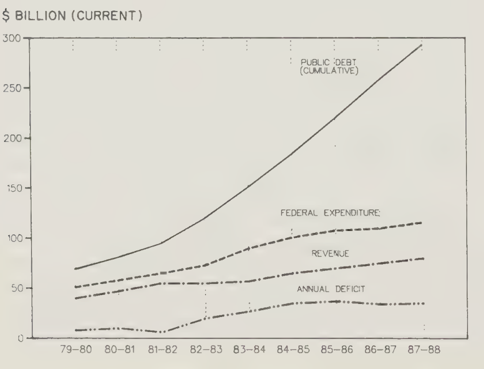


Sources: Fiscal Plan (federal), February 1984; and "A New Direction for Canada", Department of Finance, November 1984

During the fiscal years 1979-80 to 1983-84, federal revenues increased by 46%, while expenditures grew by 75%. This resulted in a rise in the public debt from $69 billion in 1979 to $180 billion in 1984, a growth of 161%. Over the next 4 years, 1984-85 to 1987-88, revenues are expected to increase from $67 billion to $88 billion, a growth of over 31%, with expenditures rising by about 17%. In 1984-85, federal revenues are expected to be about $67 billion, which will provide for about 71% of government expenditures. With revenues continuing to fall short of federal commitments, deficit financing will be needed to make-up the difference. From 1984-85 to 1987-88, the public debt is expected to increase by about 61%, which is significantly lower than the 161% growth that occurred between 1979 and 1984.

Figure 2 shows the relationship and trend among revenue, expenditures, deficit and public debt.

FIGURE 2 FISCAL DATA



Sources: Fiscal Plan, February 1984; Ministry of State for Economic and Regional Development (MSERD) report, April 15, 1984; and "A New Direction for Canada", November 1984

Government expenditures can be broken down into "statutory" and "non-statutory". The statutory items are specified in existing legislation and must receive top priority for funding. Averaged over 1979-80 to 1984-85, statutory expenditures are over 59% of total annual federal outlays. The remaining 41% of federal expenditures consitute non-statutory items, referred to as "votes". Parliament is asked to approve the votes through Appropriation Acts. The wording and amount of the votes, as specified in Appropriation Acts, become the governing conditions for expenditures.

Figure 3 indicates the statutory and non-statutory breakdowns and shows the distribution of statutory expenditures by major government departments, averaged over 1979-80 to 1984-85.

As shown in Table 1, averaged over 1979-80 to 1984-85, four government departments are responsible for 94% of total federal statutory expenditures. The remaining 6% is spent by all other government departments, including Agriculture Canada. During this period, the average growth in government statutory expenditures has been about 14% per year, whereas Agriculture Canada's statutory expenditures increased by about 32%. However, Agriculture Canada's total expenditure (A-Base) grew by about 13% per year. This indicates that over this period some of Agriculture Canada's statutory program costs increased faster than its non-statutory expenditures.

TABLE 1 STATUTORY EXPENDITURES 1979-80 to 1984-85

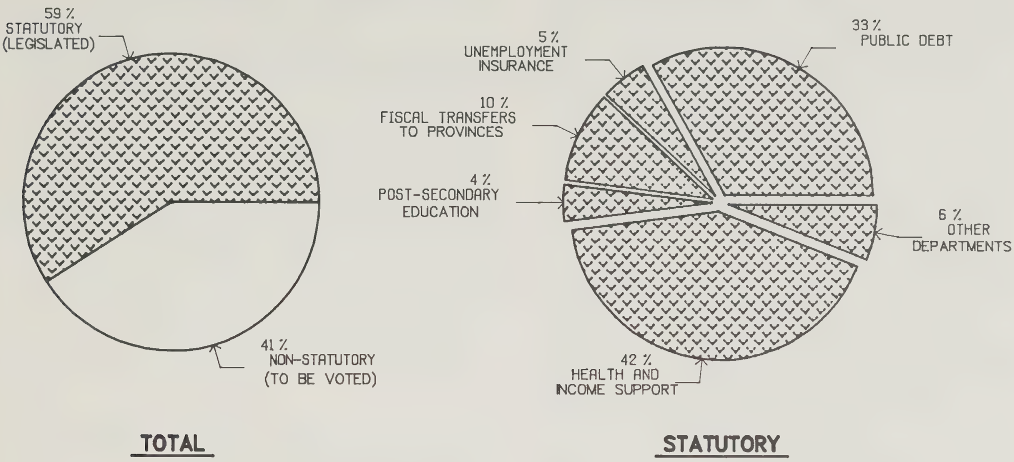
	Average %
Health and Welfare – health and income support	42
Finance – public debt	33
– fiscal transfer	10
Secretary of State – post-secondary education	4
Employment and Immigration – unemployment insurance	5
All other departments	6
Total	100

Source: Based on data from Main Estimates, Department of Finance, 1979-80 to 1984-85

For the current fiscal year 1984-85, total government expenditure forecast is $94.5 billion, of which $57.7 billion or 61% is statutory (legislated) and $36.8 billion or 39% is non-statutory (to be voted). Statutory expenditures for 1984-85 are listed in Table 2 by major government programs.

During 1984-85, Agriculture Canada will be responsible for spending up to $305 million towards departmental statutory commitments. This is approximately 24% of departmental estimates, but only about 0.5% of the total government statutory expenditures. The voted portion of total departmental expenditures is about 2.7% of the total voted expenditures of government. Total departmental

FIGURE 3 GOVERNMENT EXPENDITURES, AVERAGE PER YEAR (1979-80 TO 1984-85)



Source: Main Estimates, Department of Finance

TABLE 2 STATUTORY EXPENDITURES 1984-85

	($ billion)	(%)[1]
Health and income support	23.1	40.0
Public debt	20.4	35.2
Fiscal transfer	5.6	9.8
Post-secondary education	2.1	3.7
Unemployment insurance	2.7	4.7
Others	3.8	6.6
Total	57.7	100.0

[1]This differs slightly in percentages from the preceding table due to the use of averages over the 6-year period.

Source: Main Estimates, Department of Finance, 1984-85

estimates for 1984-85 are 1.3% of total government expenditures. It should be noted that, generally, departments with large non-statutory budgets are more vulnerable to possible reductions and cutbacks than those with a large statutory component in their A-Base.

FISCAL FRAMEWORK AND THE ENVELOPE SYSTEM

Another important dimension of the fiscal framework is the envelope system. Within the purview of the current fiscal framework, up to September 1984 total government outlays had been distributed within 10 envelopes as shown below. However, after the election, the Conservative government placed the energy envelope in the economic and regional development envelope, and the justice and legal envelope in the social development envelope. For this analysis, the envelope system prior to the election is used. (Table 3)

TABLE 3 THE ENVELOPE SYSTEM

Fiscal arrangements	– provides transfer payments to other levels of government
Public debt	– covers public debt interest and amortization costs
Economic and regional development	– includes 13 economic development departments, including Agriculture Canada
Energy	– provides for energy-related programs, including Northern Pipeline
Social affairs	– includes 11 departments dealing with social programs
Justice and legal	– covers the departments of Justice and Solicitor General
External affairs	– provides for trade and international programs
Defence	– provides for defence expenditures
Parliament	– covers the Senate, House of Commons and Parliamentary Library
Services to government	– provides services to government operations

The relative sizes of various envelopes, averaged over 1979-80 to 1983-84, for the current year 1984-85 and for the following 3 years (1985-86 to 1987-88) are shown in Figure 4.

Averaged over the 9-year period 1979-80 to 1987-88, the social affairs envelope is the largest at 40.6% and the public debt envelope the second largest at 19.7% of the total outlays of the federal government. Expenditures in these two envelopes are largely statutory. The other three major envelopes are economic and regional development at 10.6%, defence at 8.9% and fiscal arrangements at 6.2%, all of which are largely non-statutory. The remaining five envelopes are relatively small, accounting for about 14% of the government outlays, and provide for both statutory and non-statutory expenditures.

On the average, the five major envelopes noted above represent 86% per year of all envelope outlays for the period 1979-80 to 1987-88. Comparing the current year (1984-85) envelope allocations with those averaged over 1985-86 to 1987-88, the public debt and the defence envelopes will receive a larger share of the total envelope funds, while the social affairs, economic and regional development and fiscal arrangement envelopes will receive a smaller share. Since Agriculture Canada is in the economic and regional development envelope, reduction in the level of this envelope is likely to affect the funding level of the department.

ECONOMIC AND REGIONAL DEVELOPMENT ENVELOPE AND AGRICULTURE CANADA

In terms of current dollars, the percentage compound growths per year in the five major envelopes over the 1979-80 to 1987-88 period are illustrated in Table 4.

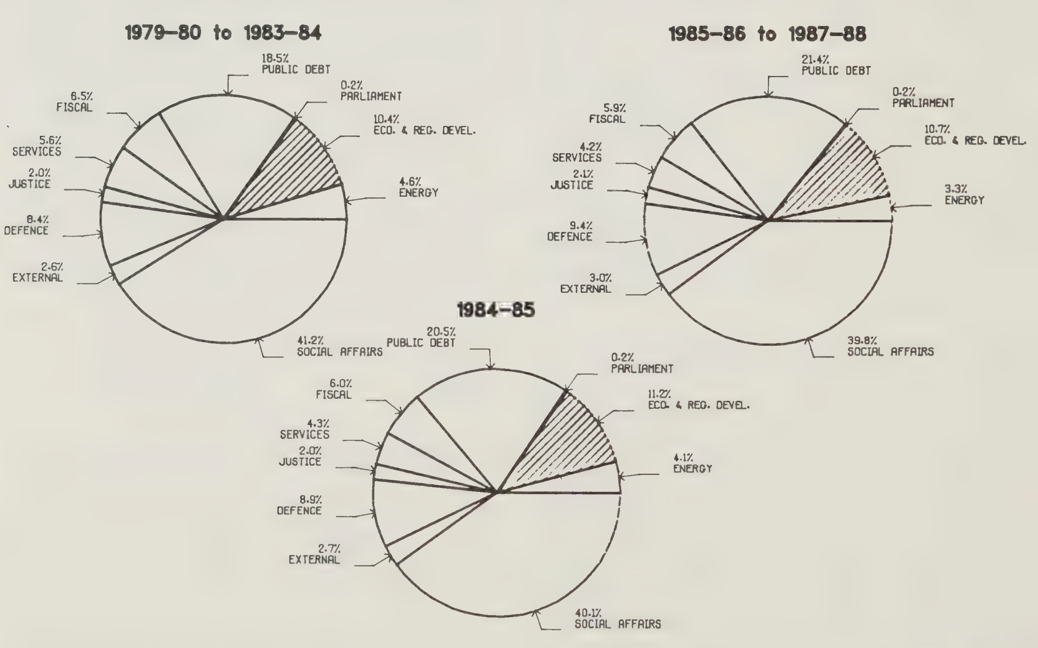
Among these envelopes, the economic and regional development envelope is the only one which will receive a smaller share of the total envelope outlays, and will continue to experience a declining future percentage growth per year. Consequently, for departments in this envelope, including Agriculture Canada, securing additional funds for new programs will be difficult.

TABLE 4 PERCENT ANNUAL GROWTH — CURRENT DOLLARS

	1979-80 to 1983-84	1984-85	1985-86 to 1987-88
Public debt	16.6	12.2	6.3
Economic and regional development	15.4	3.0	2.5
Defence	13.1	11.3	7.7
Social affairs	11.7	4.2	5.2
Fiscal arrangements	11.3	2.0	6.3

Source: Ministry of State for Economic and Regional Development (MSERD) report, April 15, 1984, and the (federal) Fiscal Plan, February 1984

FIGURE 4 SIZE OF ENVELOPES, PERCENTAGE PER YEAR



Source: Fiscal Plan, February 1984

In terms of constant dollars (1979), the annual percentage compound growth in the five major envelopes is much smaller. (Table 5)

In real terms, there is a downtrend in the funding level for the economic and regional development envelope.

The compound annual growth, in real terms (1979 dollars), in all envelopes over 1979-80 to 1983-84 has been about 3.8% per year. Over the same period, the economic and regional development envelope grew in real terms by about 8.2% per year, with Agriculture Canada showing an annual compound real growth of about 2.2%. Other departments received a larger share of the envelope growth than that allocated to Agriculture Canada. The impact of this decline is becoming increasingly evident by continuous strain on resources needed to undertake long-term projects, particularly in the areas of research and development.

Over the period 1984-85 to 1987-88, in terms of 1979 dollars, the compound growth in all envelopes is projected at about 1.4%, with the economic and regional development envelope declining at about 1.5% per year. In view of this downtrend in government spending, particularly in the economic and regional development envelope, the resource squeeze experienced over the past several years by Agriculture Canada and other departments in this envelope is likely to worsen.

TABLE 5 PERCENT ANNUAL GROWTH — CONSTANT DOLLARS (1979)

	1979-80 to 1983-84	1984-85	1985-86 to 1987-88
Public debt	9.2	8.5	2.5
Economic and regional development	8.2	(0.4)	(1.5)
Defence	5.2	7.5	3.9
Social affairs	3.7	0.8	1.3
Fiscal arrangements	3.3	(1.4)	2.4

Derived from the preceding table

POLICY RESERVES

Prior to September 1984, a special pool of money existed within each of the envelopes to fund initiatives and proposals not covered under the A-Base. This pool was called the policy reserve. Each envelope had one or more policy reserves to provide the flexibility to fund new initiatives considered necessary to support government policy. The Ministers put forward their proposals for consideration by the appropriate Cabinet committee and, if approved and ratified by Cabinet, funding for such proposals was arranged from the policy reserve and allocated accordingly by Treasury Board. While the concept of policy reserve still exists, there is currently no money in any of the reserves.

In 1983-84, the total policy reserve in the economic and regional development envelope was \$2 010 million. For 1984-85, this reserve was reduced to \$968 million, a drop of about 52%. This significantly reduced the funding of new proposals from the policy reserve. Among major departments in the economic development envelope, in 1983-84 Regional Industrial Expansion received \$676 million (34%), Transport \$338 million (17%) and Fisheries and Oceans \$289 million (14%). Agriculture Canada received the lowest level of funding from the policy reserve at \$105 million (about 5% of the total envelope).

For the period 1984-85 to 1987-88, the total commitments from policy reserves under the economic and regional development envelope were as follows.

Among departments shown in Table 6, over the 4-year period from 1984-85 to 1987-88, Agriculture Canada was to receive \$85.9 million from the policy reserve. However, since September 1984 this flexibility has been severely limited, and departments are generally required to fund new initiatives from their A-Base. This requires that departments undertake more realistic long-term planning and establish strategies and priorities to achieve their goals and objectives while supporting government policies.

Departments will also be required to remain within their A-Base. Only in exceptional cases will new funding requests be considered by Cabinet committees.

TABLE 6 POLICY RESERVES

	1984-85		1985-86		1986-87		1987-88		Total	
	\$ (million)	%	\$ (million)	%	\$ (million)	%	\$ (million)	%	\$ (million)	%
Agriculture	30.2	3.1	19.6	1.4	18.8	1.4	17.3	1.2	85.9	1.7
Fisheries and Oceans	23.5	2.4	20.8	1.5	20.1	1.5	29.4	2.2	93.8	1.8
Regional Industrial Expansion	91.0	9.5	221.6	16.2	419.1	30.5	453.5	32.6	1 185.2	23.2
Science and Technology	27.6	2.9	85.3	6.2	84.7	6.2	14.1	1.0	211.7	4.1
Transport	43.6	4.5	17.2	1.3	22.4	1.6	5.3	0.4	88.6	1.7
Others	108.4	11.1	117.6	8.6	103.4	7.5	52.6	3.7	382.0	7.6
Uncommitted	643.4	66.5	885.9	64.8	705.3	51.3	819.9	58.9	3 054.5	59.9
Total	967.8	100.0	1 368.0	100.0	1 373.8	100.0	1 392.1	100.0	5 101.7	100.0

Source: MSERD report, April 15, 1984

THE AGRI-FOOD SECTOR

The Canadian agri-food sector is a large, highly complex, diversified economic sector. In 1982, agriculture output was about $19 billion at the farm level; food worth over $30 billion was consumed "at home" and about $10 billion "away from home". For the same year (1982) agri-food exports, including fish products, were in the order of 11% of all exports by Canada, which created a trade surplus of over $6.5 billion in total net trade. The sector produces about 100 primary commodities and employs some 1.4 million people, which is about 12% of the total Canadian work force.

The policies and programs of Agriculture Canada affect some 317 000 primary producers, about 4 500 food and beverage processors, 3 100 wholesalers, 33 000 food retailers and over 50 000 food service establishments. Departmental policies also impact on receiving, storage, handling and transportation facilities, which include some 3 000 elevators and seaports, a major portion of the railway system, rural road network and trucking, cold storage facilities, suppliers of inputs and related industries. Agricultural research and technology development, production of fertilizers, pesticides and insecticides, and disease control and contamination levels in crops, animals, poultry, dairy products and other farm outputs are also affected by policies of the department.

Departmental policies also affect ecological systems, water quality, irrigation projects, soil conservation and atmospheric pollution. The department is responsible for negotiating and implementing of agricultural sectoral agreements with the provinces. Crown corporations and agencies under the Minister of Agriculture, agricultural marketing agencies and cooperatives, and wheat and grain pools also assist the agri-food sector in determining such things as price structures, quotas, and inspection standards.

AGRICULTURE CANADA

The departmental A-Base for the fiscal year 1984-85 is $1 267.9 million and 11 686 person-years, which includes the department and the Canadian Grain Commission. The total budgetary estimates for Agriculture Canada are $1 298 million and 11 816 person-years, which include the departmental A-Base as noted above and the operating budgets of the Canadian Dairy Commission, the Livestock Feed Board of Canada and Canagrex. The operating estimates of the Farm Credit Corporation are non-budgetary, although loanable funds are drawn as statutory appropriations under the Farm Credit Act and the Farm Syndicate Credit Act. Data used are for the period 1981-82 to 1984-85, which is subsequent to the last reorganization in the department. It should be noted that changes arising due to the merger of Forestry and the Grains group with Agriculture Canada are not taken into account.

Departmental A-Base

The A-Base furnishes the resources needed by the department and the Canadian Grain Commission to provide for the performance of work, the supply of goods and the rendering of services to the government and the agri-food sector through programs as defined in the Main Estimates. (Table 7)

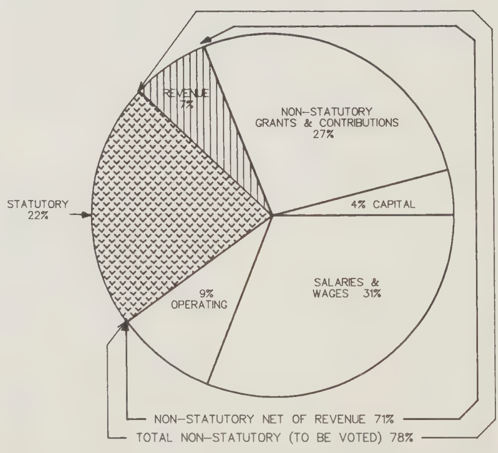
Similar to the government expenditure pattern, Agriculture Canada's A-Base has two major components: the statutory portion as legislated in the statutes and the non-statutory component voted annually by Parliament. Averaged over the 4-year period 1981-82 to 1984-85, the departmental statutory expenditure is about 22% and the non-statutory 78% of the A-Base. The average distribution of the A-Base for the same period is shown in Figure 5.

TABLE 7 A-BASE ALLOTMENT 1984-85

	$ million
Departmental Administration Program	51.5
Agri-food Development Program, including: – Agricultural Stabilization Board – Agricultural Products Board – National Farm Products Marketing Council	959.0
Agri-food Regulation and Inspection Program, including Race Track Supervision	215.8
Canadian Grain Commission	41.6
	1 267.9

Source: Main Estimates, 1984-85

FIGURE 5 AGRICULTURE CANADA A-BASE, AVERAGE PER YEAR (1981-82 TO 1984-85)



Source: Multi-year operational plans, Agriculture Canada

The department receives certain revenue for services rendered under departmental programs, including such things as return on investments, race track, and grain inspection and weighing. In 1984-85 the department is expected to receive about $85.4 million in revenue. It has recently been proposed that as of 1985-86 users commence paying for some of the services currently provided free by the department. Funds thus realized are likely to be used to reduce the departmental outlays. The 1985-86 target for cost recovery is $32.3 million, which will be mostly from departmental expenditure on inspection and quality assurance services.

For 1984-85, the breakdown of the departmental A-Base is illustrated in Table 8.

As noted in Figure 5, the average statutory expenditure of the department is 22% of its A-Base, whereas the average government statutory component is 59% of the total federal expenditures. This indicates that in comparison to the government as a whole, Agriculture Canada has a higher level of non-statutory budget that allows the department more flexibility in resource management to suit the needs of departmental programs. On the average, non-statutory grants and contributions, and salary and wages account for about 58% of the departmental A-Base, leaving about 13% for capital projects and other operating costs.

TABLE 8 BREAKDOWN OF DEPARTMENTAL A-BASE 1984-85

	$ million	%
Statutory (including statutory personnel costs)	305.3	24.0
Non-statutory grants and contributions	324.2	25.6
Capital projects	85.8	6.8
Salaries and wages (statutory benefits excluded)	382.6	30.2
Other operating costs	170.0	13.4
Total	1 267.9	100.0
Less revenue	85.4	6.7
Expenditure net of revenue	1 182.5	93.3

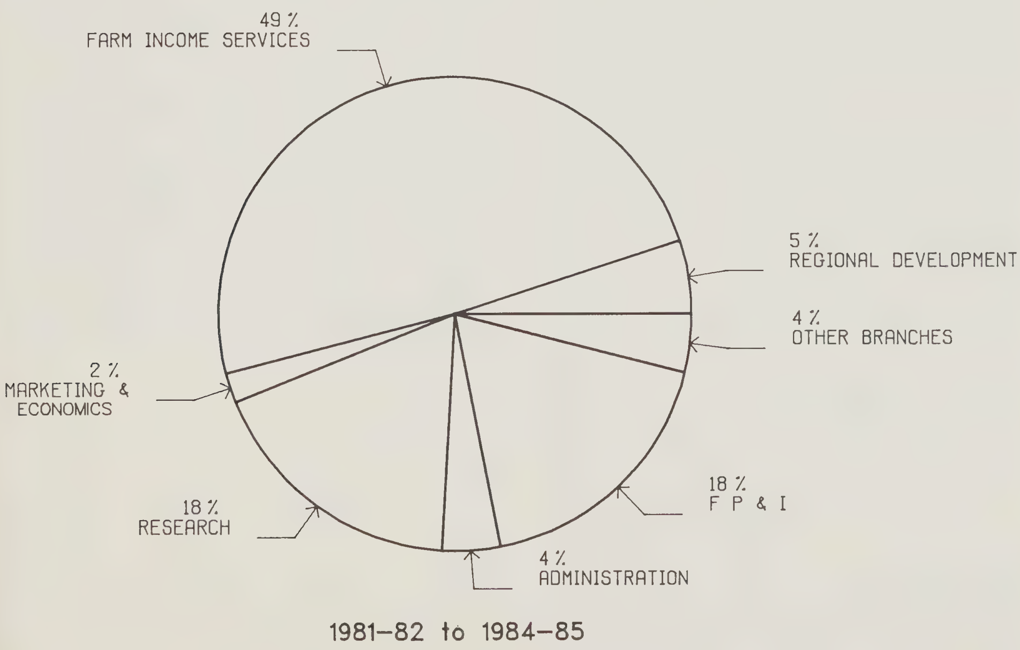
Source: Main Estimates 1984-85

Branches

For departmental operations and management purposes, the A-Base funds are allocated by branches. Figure 6 indicates the distribution of the A-Base by branch, averaged over the 4-year period from 1981-82 to 1984-85.

As noted above, the Farm Income Services (FIS) Branch utilizes about 49% of the A-Base for making payments towards farm income stabilization, including

FIGURE 6 DEPARTMENTAL A-BASE BY BRANCH, AVERAGE PER YEAR



Sources: Multi-year operational plans, Agriculture Canada

deficiency payments, the dairy program, and the crop insurance program. These funds are drawn both from the statutory allocations and from the non-statutory grants and contributions portion of the A-Base. Income stabilization payments made to primary producers by this branch have significant socioeconomic impact on the sector, the regions and national economy. This is an income redistribution process that helps farmers offset some of their losses in the past years and hence sustain sectoral viability.

Over the period 1981-82 to 1984-85, Research Branch and Food Production and Inspection Branch each received an average of about 18% of the A-Base. This left about 15% of the A-Base to be shared by the remaining branches excluding FIS. Programs under branches other than FIS are mostly non-statutory, which allows them greater program flexibility.

Over the 4-year period 1981-82 to 1984-85, the compound annual growth in branch expenditures has been as illustrated in Table 9.

In spite of its dollar size, the average growth over this period (1981-82 to 1984-85) in the Farm Income Services Branch has been 6.6%, which is the lowest among all branches. In terms of constant dollars (1982) over the 5-year period 1983-84 to 1987-88, stabilization payments and transfers to provinces are expected to decline by 3.3% per year. In terms of current dollars, the growth is expected to be in the order of 0.4% per year, which is well below the expected average inflation of about 5% per year for this period. This indicates that growth in stabilization payments is not large and it is well below the growth in other branches of the department.

1984-85 is the first full year that Prairie Farm Rehabilitation Administration will be in Agriculture Canada. Therefore, its growth rate in the department cannot be determined at this time.

TABLE 9 BRANCH EXPENDITURE GROWTH

	1981-82 to 1984-85 %
Administration	12.6
Research	14.0
Marketing and Economics	10.0
Regional Development	18.9
Farm Income Services	6.6
Food Production and Inspection	8.9
Others (Grain Commission, NFPMC etc.)	11.6
Total	82.7

Source: Agriculture Canada multi-year operational plans

Salary costs and person-years

A comparison of salary costs per person-year (PY) between the government and Agriculture Canada indicates that government costs per PY are higher than departmental costs. Such costs include salaries, wages and employee benefits. Averaged over the 6-year period 1979-80 to 1984-85, these costs are as in Table 10.

As noted, the average salary costs in Agriculture Canada are 35.8% of the departmental A-Base, and for the federal government 15.5% of its total annual expenditures. This indicates the labor intensive and highly service nature of the department. The large statutory programs in several other departments tend to reduce the ratio of federal salary dollars to total expenditures.

At the same time, over the 6-year period 1979-80 to 1984-85, in terms of constant dollars (1979), the average salary costs per person-year for the department are about 9% lower than those of the government. The annual average percentage increase in salary cost per person-year in constant dollars (1979) is also lower for the department than for the government as a whole.

The branch person-year distribution over the 4-year period 1981-82 to 1984-85 is shown in Table 11.

Over the 4-year period 1981-82 to 1984-85, the largest person-year growth (165) has been in the Finance and Administration Branch, achieved through transfers from other branches. This branch has, on the average, about 8% of the total person-years for the department. The increase is due to the provision of expanded administrative and financial services both at headquarters and in the regions, expansion of Systems and Consulting services and computerization of financial recording and reporting systems in the department.

TABLE 10 SALARY COSTS

	Average salary costs		Average PY	Average salary costs per PY		Average % increase per PY
	Costs $ million	% of total		Current $	Constant $ 1979	Constant $ 1979
Federal government	10 875	15.5	325 832	33 376	26 170	2.4
Agriculture Canada	339	35.8	10 907	31 081	24 020	1.3

Source: Main Estimates

TABLE 11 BRANCH PERSON-YEAR DISTRIBUTION

Branch	1981-82	1982-83	1983-84	1984-85	Average % of total	Total PY increase	% change
Administration	803	917	923	968	8	165	21
Research	3 673	3 647	3 619	3 594	33	(79)	(2)
Marketing and Economics	296[1]	275	266	269	3	(27)	(9)
Regional Development	585	573	601	618	7	33	6
Senior ADM and FIS	69[1]	92	119	118	1	49	71
FP&I and Race Track	4 419	4 388	4 361	4 302	40	(117)	(3)
Others[2]	863	896	932	937	8	74	9
PFRA[3]	–	–	–	881	–	881	–
Total	10 708	10 788	10 821	11 687	100	979	9

[1] Prorated; Senior ADM Organization (SADMO) was formed in 1982-83
[2] Includes Grain Commission, National Farm Products Marketing Council, etc.
[3] PFRA transferred to Agriculture Canada during 1983-84. 1984-85 is the first full year for it to be in Agriculture Canada.
Source: Agriculture Canada multi-year operational plans

Reductions have been in the three major program branches: Food Production and Inspection by 117 PYs, Research by 79 PYs and Marketing and Economics by 27 PYs, a total of 223 PYs. Some of these PYs were transferred to other branches.

As noted, the Regional Development Branch, the Farm Income Services Branch and other branches also received additional PYs, some of which were additional allocations by Treasury Board. Due to the transfer of PFRA to Agriculture Canada, the department gained 881 person-years.

Expenditures in the provinces by Agriculture Canada and the provinces

Agriculture Canada provides assistance directly or jointly with provincial governments to guide and support development of the agri-food sector. This includes financial assistance, and technical advice and expertise for projects in research, production and marketing aimed at sectoral development. Over the 5-year period 1978-79 to 1982-83, average expenditures which can be allocated to specific provinces, excluding the National Capital Region, were about $750 million per year in the areas shown in Table 12.

TABLE 12 PROVINCIAL EXPENDITURES

	$ million	Percent of total
Research	97	13
Marketing and production	221	29
Crop insurance	102	14
Stabilization	330	44
Total	750	100

Source: Federal Agri-Food Expenditure Data, Regional Development Branch, Agriculture Canada.

This does not include federal agricultural expenditures in the provinces by departments other than Agriculture Canada. Agricultural expenditures by other federal departments are discussed separately.

The average distribution of expenditures by Agriculture Canada in the provinces is shown in Figure 7.

Over this period, Quebec was the largest recipient of departmental expenditures among the provinces, with Ontario close behind. Crop insurance payments in New Brunswick, Nova Scotia and Newfoundland, and stabilization payments in Newfoundland were negligible. The National Capital Region is shown separately and not as a part of the province of Ontario.

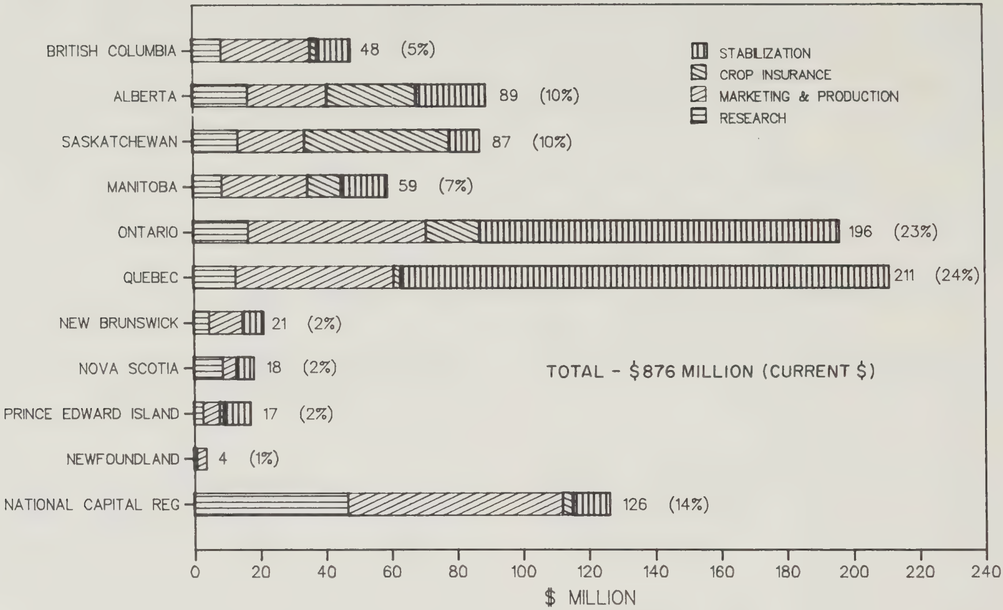
In 1982-83, total agricultural expenditure in the provinces by Agriculture Canada and provincial governments was $2 127 million. The department funded 47% ($1 009 million) of the total, with provinces providing the remaining 53% ($1 118 million). The major expenditure items shared by the federal and provincial governments and their percentages are illustrated in Table 13.

Marketing and production is an important area for Agriculture Canada as well as for the provinces, accounting for 34% of the total costs. Crop insurance and stabilization, and research programs are largely funded by Agriculture Canada, involving subsidy payments and agricultural research facilities in the provinces. The provinces are fully responsible for extension and education programs.

Economic and regional development agreements (ERDAs)

Although general development agreements with the provinces have existed for many years, during the fiscal year 1983-84 ERDAs were introduced to further stimulate economic development in the provinces. Under ERDAs, subagreements are being developed by departments having

FIGURE 7 EXPENDITURES BY AGRICULTURE CANADA IN THE PROVINCES, AVERAGE PER YEAR (1978-79 TO 1982-83)



Source: Federal agri-food data compiled by Regional Development Branch, Agriculture Canada

TABLE 13 SHARED EXPENDITURES

	Federal funds ($ million)	Provincial funds ($ million)	Total ($ million)
Marketing and production	304 (42%)	426 (58%)	730 (34%)
Crop insurance and stabilization	458 (71%)	184 (29%)	642 (30%)
research	181 (76%)	58 (24%)	239 (11%)
Extension and training	– –	144 (100%)	144 (7%)
Other related services	66 (18%)	306 (82%)	372 (18%)
Total	$1 009 (47%)	$1 118 (53%)	$2 127 (100%)

Source: Government Expenditures Related to Agriculture (GERTA), Department of Finance

sectoral responsibilities. A number of agricultural subagreements have already been finalized by Agriculture Canada and the provinces, while several others are currently under negotiation. During the 5-year period 1984-85 to 1988-89, departmental expenditures in the provinces are expected to be supplemented by these agreements. Federal funding levels for agricultural subagreements are shown in Table 14.

To date, subagreements have been signed with Saskatchewan, Manitoba, New Brunswick and Prince Edward Island, while only a federally funded agricultural (ERDA-related) initiative exists in Quebec. However, this situation is likely to change in the future.

Crown corporations

The Minister of Agriculture is responsible for eight agricultural crown corporations and agencies. Their operating funds and PYs for the fiscal year 1984-85 are illustrated in Table 15.

TABLE 14 AGRICULTURAL SUBAGREEMENTS

Province	Approved funding level ($ million)
British Columbia	–
Alberta	–
Saskatchewan (including PFRA)	46
Manitoba	23
Ontario	–
Quebec	5
New Brunswick	25
Prince Edward Island	26
Newfoundland	–
Total	125

Source: Data from Regional Development Branch, Agriculture Canada

TABLE 15 CROWN CORPORATIONS

Crown corporations	$ million	PYs
Agricultural Stabilization Board	1.4	59
Agricultural Products Board	0.1	2
Canagrex (discontinued effective March 31, 1985)	5.4	28
Livestock Feed Board of Canada	1.5	25
Canadian Grain Commission	41.6	910
Canadian Dairy Commission	6.5	77
National Farm Products Marketing Agency	1.8	27
Total (budgetary)	58.3	1 128
Farm Credit Corporation (non-budgetary)	54.2	660
Total	112.5	1 788

Source: Annual reports from crown corporations, 1983-84

AGRICULTURAL EXPENDITURES BY OTHER DEPARTMENTS

In addition to Agriculture Canada, there are several other federal departments involved in agri-food initiatives. About half of total federal expenditures in the agri-food sector are undertaken by departments other than Agriculture Canada. For example, Transport Canada is involved in transportation of agricultural commodities, and the Department of External Affairs is involved with agricultural trade and international aid. Since these functions are not used exclusively by the agri-food sector, it is almost impossible to accurately determine total federal agricultural expenditures in Canada.

The average annual expenditure by all federal departments over the 4-year period 1978-79 to 1981-82 was $1 700 million, with Agriculture Canada responsible for about $881 million per year. The average percentage distribution of agricultural expenditure by major government departments over the same period is shown in Figure 8.

Over the 5-year period 1978-79 to 1982-83, there were 11 different departments involved in programs having a direct impact on agriculture. These are indicated in Table 16 in the order of their dollar size, for the fiscal year 1982-83.

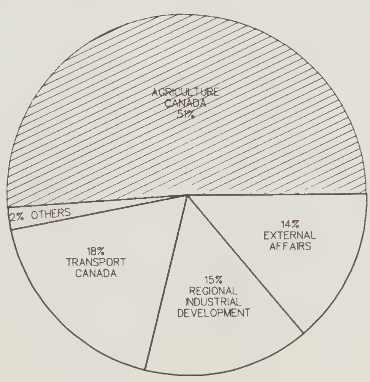
It is difficult to accurately determine what percentage of agricultural expenditures by departments other than Agriculture Canada are subsidies. However, a review of their agricultural programs indicates that it is substantial.

Within Agriculture Canada, averaged over 1978-79 to 1981-82, income stabilization constitutes about 54% per year of annual departmental expenditures, whereas agricultural subsidies by other federal departments averaged about 90% of their total expenditures on agricultural programs. In total, agricultural subsidies constitute about 71% of total federal expenditures on agriculture, comprising 28% from Agriculture Canada and 43% from other departments.

Averaged over 1978-79 to 1981-82, agricultural expenditures in the provinces by Agriculture Canada, Regional and Industrial Expansion, Transport Canada and others, excluding External Affairs, are shown in Table 17. External Affairs' agricultural programs are structured such that they cannot be broken down by province.

Over the 4-year period 1978-79 to 1981-82, excluding agricultural expenditures by External Affairs, the three prairie provinces received an annual average of 39% of the total allocations by federal departments. The four Atlantic provinces received over 6% per year. Quebec and Ontario together received about 25%, with major contributions from Agriculture Canada. Saskatchewan was the largest recipient at 21% per year. During this period Ontario was the largest contributor to Agriculture Gross Domestic Product (GDP), followed by Alberta and Saskatchewan. On the basis of Agriculture GDP distribution, Ontario and Alberta were the lowest recipients of federal contributions, while Newfoundland was the largest followed by the other three Atlantic provinces.

FIGURE 8 FEDERAL EXPENDITURE IN AGRICULTURE BY MAJOR DEPARTMENTS, AVERAGE PER YEAR (1978-79 TO 1981-82)



Source: Regional Development Branch, Agriculture Canada

TABLE 16 DEPARTMENTAL PROGRAMS AFFECTING AGRICULTURE

Department	$ million	Percent of total	Major programs
1. Agriculture	1 010	44	Stabilization, crop insurance, water fowl damage, market development, regulatory and inspection, feed grains and freight, advance payment for crops, cold storage, grain inspection and weighing, research, race track, Economic and Regional Development (ERDA) agricultural subagreements, regional development, Prairie Farm Rehabilitation (PFRA) (since 1983-84)
2. Transport	622	27	Payments under the Railway Act, Maritime and Atlantic freight rates, branch line rehabilitation, grain transportation
3. External Affairs	306	13	World food and aid programs, Food and Agriculture Organization, International Development Research Centre and international organizations, federal-provincial voluntary agriculture development, grain export credit, export market development
4. Regional Industrial Expansion (including Industry, Trade and Commerce	231	11	Western Grain Stabilization, prairie grain advance payments, emergency herd maintenance, rapeseed utilization assistance, protein, oil and starch marketing, agriculture rural development, ERDAs, regional development incentives, PFRA (to Agriculture in 1983-84)
5. Employment and Immigration	43	2	Farm labor pool and seasonal employment, training and new skills
6. Health and Welfare	27	1	Food quality and health hazards
7. Science and Technology	18	1	Industrial research, research and strategic grants, plant biotechnology institute
8. Others Supply and Services (Statistics Canada) Indian Affairs and Northern Development	18	1	Agriculture statistics, energy conservation, contribution to indigenous people for agriculture development, land development, land inventory, farm vehicle conversion, crop depredation due to waterfowl
Total	2 283	100	

TABLE 17 AVERAGE AGRICULTURAL EXPENDITURES, 1978-79 TO 1981-82

Province/ region	$ million Agric.	$ million RIE	$ million Trans.	$ million Others	$ million Total	% of Total	% Agric.[1] prod. (GDP)	% of popula-tion
Newfoundland	4	5	1	3	13	0.7	0.2	2.3
Prince Edward Island	17	8	4	1	30	1.7	1.0	0.5
Nova Scotia	17	7	3	2	29	1.7	1.2	3.5
New Brunswick	19	8	5	2	34	2.0	1.2	2.9
Quebec	202	18	3	10	233	13.4	12.3	26.4
Ontario	193	5	–	14	212	12.2	26.7	35.4
Manitoba	57	36	26	5	124	7.1	6.6	4.2
Saskatchewan	84	103	170	10	367	21.1	21.3	4.0
Alberta	87	37	59	4	187	10.8	23.3	9.2
British Columbia	46	11	1	5	63	3.6	6.2	11.3
National Capital	155	2	1	26	184	10.6	–	–
Unallocated	–	–	33	229[2]	262	15.1	–	0.3[3]
Total	881	240	306	311	1 738	100	100	100

[1]1981 Census, Provincial Agriculture GDP

[2]External Affairs Expenditure

[3]Yukon and Northwest Territories

Source: Data from Regional Development Branch, Agriculture Canada.

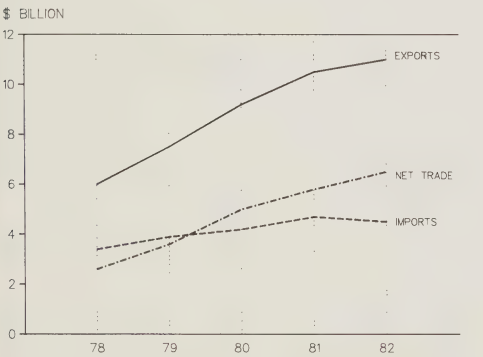
Agricultural trade

Trade is important to the agri-food sector, but even more so to the primary agriculture industry which is strongly supported by Agriculture Canada. Due to complexities involved in obtaining data, it is difficult to determine the agri-food trade-related expenditures by Agriculture Canada. They are, however, believed to be substantial. Some comparisons are drawn to indicate the relative position of agri-food trade and its value to the economic well-being of Canada.

Agri-food exports comprise primary agriculture products, food and beverage, fish products and tobacco. Averaged over the 5-year period from 1978 to 1982, agri-food accounted for 12% of all exports from Canada. During the same period, agri-food imports averaged 6% of all imports into Canada. This resulted in agri-food trade contributing 19% to the total trade surplus. Growth in agri-food trade over this period is shown in Figure 9.

The agri-food sector is the only one that made a continuous positive contribution to net trade during this period. The average annual growth in the value of agri-food trade was 26%, the second largest among all trading sectors in Canada. Over the same period, net trade in primary agricultural products also grew continuously and increased by 35%. Net trade in food and beverage, fish products and tobacco grew by an average of 6% per year.

FIGURE 9 AGRI-FOOD TRADE (1978-82)

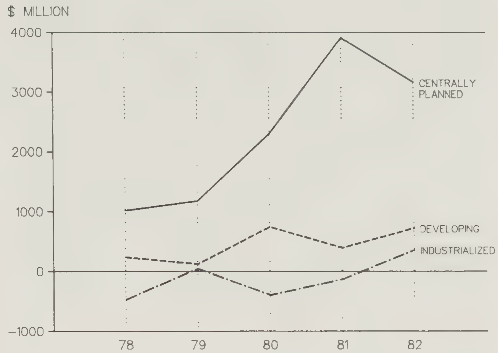


Source: "Commodity Trade by Industrial Sector", Industry, Trade and Commerce, August 1983

By country grouping, Canadian agricultural trade was highest with centrally planned countries and lowest with industrialized countries, as shown in Figure 10.

Over the 5-year period 1978-79 to 1981-82, Canada had a net agricultural trade in the order of $10.6 billion with centrally planned countries and $2.2 billion with developing countries. For the same period there was a deficit of $596 million in agricultural trade with developed countries. This is contrary to the overall trade pattern for Canada which is largely with developed countries, and of which roughly 70% is with the United States alone. Agricultural trade does not follow this pattern.

FIGURE 10 NET TRADE BY COUNTRY GROUPING (1978-82)



Source: *Handbook of Selected Agricultural Statistics*, Agriculture Canada, 1983

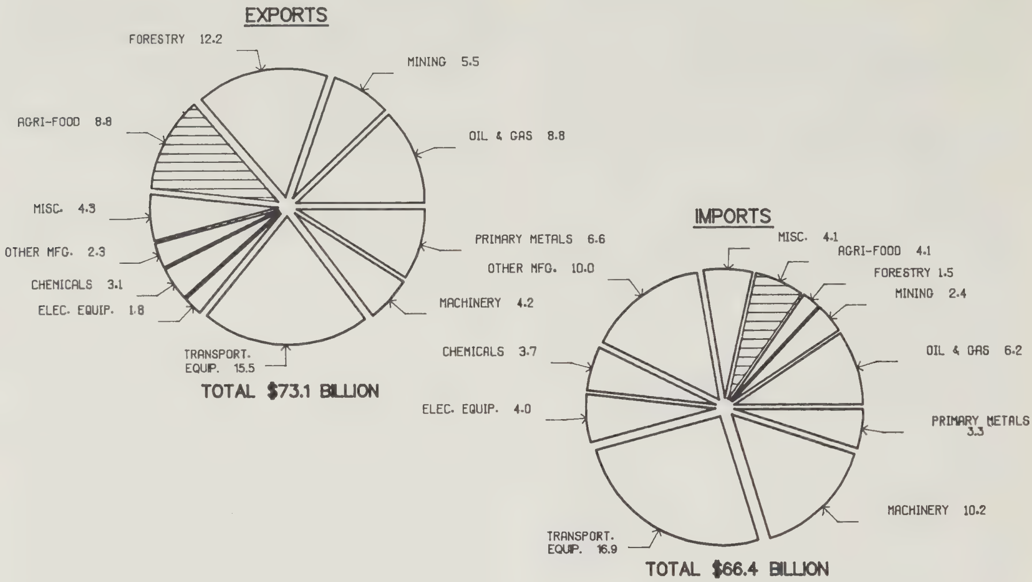
During the same 5 years, total annual exports of primary agricultural products averaged 10.3% of all exports from Canada. The total annual imports of primary agricultural products averaged 7.5% of all imports into Canada. The average export and import of major trading commodities in Canada is shown in Figure 11.

As indicated above, total average annual exports during this period were $73.1 billion and imports were $66.4 billion, giving a net average trade balance of $6.7 billion per year in favor of Canada. Among all major commodities traded, the largest average positive trade balance of $10.7 billion was generated by the forestry sector. The agri-food sector was next at $4.7 billion. The largest deficit was generated by the "other manufacturing" sector at $7.7 billion, and the machinery sector was next with an average deficit of $6 billion per year.

Figure 12 shows the net trade position of 10 major commodities over the 5-year period from 1978 to 1982.

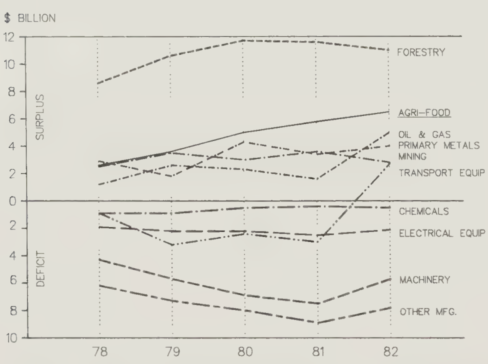
Over this period, the primary industries have consistently and continuously contributed to the trade surplus. The secondary industries have continuously generated deficit, except transport equipment which showed a surplus for the year 1982. This deviation in the usual deficit pattern of this sector has been due to the New York Subway contract awarded to Bombardier Canada. As indicated in Figure 12, only the agri-food sector has had a consistent growth, while all others show declines at one time or another during this period.

FIGURE 11 EXPORTS AND IMPORTS — MAJOR COMMODITIES, AVERAGE PER YEAR (1978-82)



Source: "Commodity Trade by Industrial Sector", Industry, Trade and Commerce, August 1983

FIGURE 12 NET TRADE — MAJOR COMMODITIES (1978-82)



Source: As per Figure 11

SUMMARY

High unemployment, falling profits, long-term tax credits held by manufacturing firms and businesses, and reduced private investment have resulted in declining government revenues. Only about 71% of government expenditures are covered by the revenues received. The current public debt (cumulative deficit in December 1984) is over $180 billion, the service cost of which is about 22% of the total annual government budget. Large social welfare programs consume over 27% of the budget. These factors, along with other statutory commitments, significantly reduce the expenditure flexibility of government.

Over the past several years, Agriculture Canada received an average annual funding increase of less than half the rate of growth in federal expenditures. Yet the department has continued to provide the expected level of service to its clients. This has affected some departmental programs, particularly in the research area. The Agri-Food Strategy has not yet been funded, even though it was approved by Cabinet in 1981. With increasing pressure to reduce expenditures, the department is likely to face further cutbacks in resources. It should be noted that about 80% of the departmental A-Base is non-statutory, which is

likely to be under closer scrutiny than statutory programs which are protected by legislation. As is the case in other areas of the government, the department will have to consider its priorities carefully.

Averaged over 5 years, about 86% of the departmental expenditures are in the provinces, confirming that Agriculture Canada is a major contributor to regional development. However, Agriculture Canada's expenditures are less than half of the total expenditure by the federal and provincial departments of agriculture. Analysis of these expenditures indicates that the provinces place a strong emphasis on marketing and production, while crop insurance, stabilization and research are largely funded by the federal government. Extension and training services are wholly provincial.

Agriculture Canada is responsible for only about half of the total federal expenditure in the agri-food sector. The remaining half is provided by departments of Transport, External Affairs, Regional Industrial Expansion and a number of other departments with lesser interests. Some of the agricultural programs handled by departments other than Agriculture Canada are related to their specific sector responsibilities.

In view of the large number of federal and provincial agriculture initiatives, a closer interdepartmental and federal-provincial liaison could improve the efficiency of delivering agricultural programs.

Agri-food trade is not only important to the sector, it also has a major impact on the Canadian balance of trade. In terms of net trade, this sector is the second largest and the only one that has made a continuously increasing contribution to the trade surplus. Due to the growing importance of agricultural commodities on the world market, this sector is not only important to the health and well-being of Canadians, it is crucial to reducing hunger and famine situations throughout the world. With regard to agri-food exports and aid programs, international trade patterns are changing due to emerging protectionist policies, particularly in the EEC countries and the United States. The less developed countries are facing serious credit difficulties, making the Canadian trade situation highly vulnerable. At the same time, the Canadian government must continue to fulfill its agri-food-related commitments to many nations around the world. Agri-food issues are among the most current matters of concern to developed, centrally planned and developing countries. These and other factors will have an important impact on future agri-food trade strategies and mechanisms and growth patterns of the agri-food sector in Canada.

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[1] Ish Singhal is a senior advisor with the Corporate Planning Section, Strategic Planning Directorate, Agriculture Canada. The author gratefully acknowledges valuable comments received from Dr. Douglas Hedley, Dr. Brian Perkins, Mr. Mike Gifford and Mr. Don Loken, as well as the assistance in obtaining regional data from Mr. Marcel Huot, all from Agriculture Canada.

Federal government expenditures in the agri-food industry 1970-71 to 1982-83

M. Rodier[1]

INTRODUCTION

Federal government involvement in the Canadian agri-food industry includes programs and activities designed to stimulate development of the industry. The major components of this involvement are research, crop insurance, stabilization, financial assistance, transportation, marketing, information and regional development, as well as inspection services and food aid.

This article provides an inventory of the programs and activities for the industry and a breakdown of expenditures by region and commodity for the fiscal years 1970-71 to 1982-83. It represents a continuation of the work already carried out by Agriculture Canada in 1977, and updated by George L. Brinkman of the University of Guelph in 1981. Arbitrary allocations and interpretations had to be made in preparing the tables of expenditures by region and commodity because the necessary information was unavailable or incomplete in some cases. Trends over time and the relative size of expenditures, however, are accurately reflected.

It should be noted that the amounts appearing in this report are the sums contributed by the government to various existing funds. They do not necessarily represent the final payments made to farmers. For example, in the case of crop insurance and western grain stabilization, the amounts were recorded when the federal government made its contributions to the funds and not when the funds were actually used to compensate producers.[2]

The references used for this study were the Public Accounts of Canada and the annual reports of the departments concerned. The breakdown of programs and activities by region and commodity is based on information provided by the appropriate services of the departments concerned.

The programs and activities listed in the inventory were arranged by department, using the system of the Public Accounts of Canada. For example, expenditures of Transport Canada include expenditures of both the Department of Transport and the Canadian Transport Commission.

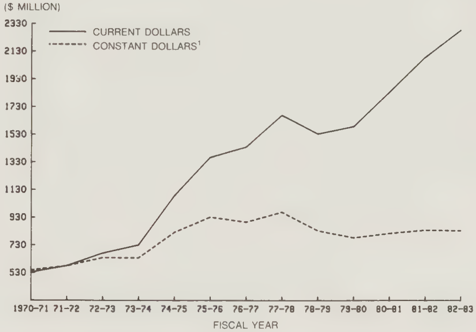
In the Public Accounts of Canada, expenditures are divided into three main categories: operating expenditures, capital expenditures, and grants. In calculating the breakdown by region and commodity, no distinction was made among these three categories. For example, a capital expenditure is considered as such as soon as the fixed asset is purchased. The expenditure is then allocated to one or more regions and to one or more commodities without using any method of depreciation. The same procedure is followed for grants used to purchase fixed assets, e.g. railway cars for grain transportation.

TOTAL EXPENDITURES

From 1970-71 to 1982-83, federal expenditures in the agri-food industry rose in nominal terms by over 300%. A particularly sharp rise was registered between 1973-74 and 1977-78. In real terms (after adjustment for the gross national expenditure implicit price index), the increase was only 52%. Real expenditures peaked in 1977-78 and decreased slightly in the years after that. The trend is illustrated in Figure 1.

Although federal expenditures in the agri-food industry increased, their percentage share of total government expenditures (excluding expenditures for service of the public debt) actually decreased over the years. For example, in 1970-71, the ratio was 4.67%. By 1982-83, it had slipped to 2.92%.

FIGURE 1 FEDERAL EXPENDITURES IN THE AGRI-FOOD SECTOR, IN CURRENT AND CONSTANT DOLLARS, 1970-71 TO 1982-83



1 Gross national expenditures, adjusted to the implicit price index, (1971 = $100)

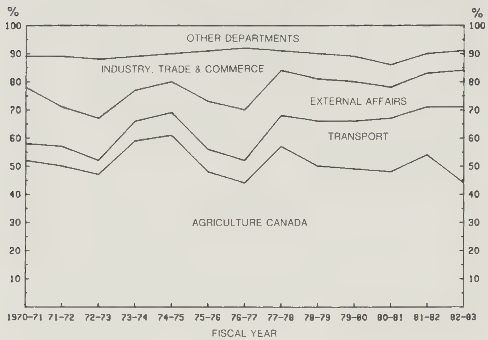
EXPENDITURES BY DEPARTMENT

Figure 2 shows that the agri-food expenditures of most departments followed a consistent pattern until 1977-78.

The amounts spent by Agriculture Canada represent about 50% of the federal total. The share of the Department of Transport has changed significantly since 1978-79. In 1982-83, it accounted for 27% of the total, up from 6% in 1970-71. This increase is related to the transportation of western grain and the rebuilding of railway branch lines on the prairies. The share of External Affairs dropped slightly over the period. The expenditures of Industry, Trade and Commerce were subject to wide swings until 1978. After that, the department's share fell sharply to the benefit of Transport. The share of other

departments, such as Employment and Immigration and Regional Economic Expansion, remained fairly constant at about the 10% level.

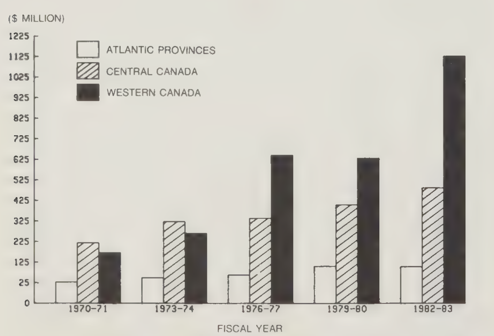
FIGURE 2 FEDERAL EXPENDITURES IN THE AGRI-FOOD SECTOR, BY PERCENTAGE AND DEPARTMENT, 1970-71 TO 1982-83



EXPENDITURES BY REGION AND COMMODITY

As shown in Figure 3, the amounts allocated to the Atlantic region increased, but not nearly to the same extent as in the other regions. Each of the Atlantic provinces showed the same rate of increase. In general, the largest amounts were registered in the fruit and vegetable category, although the allocations were divided up differently among the provinces. For example, the amounts allocated for fruits and vegetables in Prince Edward Island rose 6% at the expense of those in Nova Scotia. Financial assistance allocated for dairy cattle was also substantial. With the exception of Newfoundland, which received smaller amounts, expenditures for dairy cattle were fairly evenly divided among the Maritime provinces.

FIGURE 3 FEDERAL EXPENDITURES IN THE AGRI-FOOD SECTOR, BY REGION, 1970-71 TO 1982-83



Federal agri-food expenditures in central Canada showed a continuous increase until 1975-76. The sharp drop that occurred in 1976-77 (Table 2) can be explained by the fact that, from that time on, the National Capital Region was accounted for separately. At the beginning of the period under review, Quebec received less than Ontario. In 1976-77, this situation was reversed. Again, the fact that the National Capital Region was accounted for separately partly explains the reversal. It should be noted that dairy cattle, which are primarily concentrated in Quebec, was the category receiving the most assistance.

From 1970-71 to 1982-83, central Canada received the bulk of assistance; however, both the Atlantic and central regions registered increases. Expenditures in eastern Canada were allocated mainly for livestock.

On average in eastern Canada, the Atlantic region received about 15% of expenditures while Quebec and Ontario received 45% and 40% respectively.

Whereas expenditures in eastern Canada were allocated mainly for livestock, in western Canada they went primarily to the grains and oilseeds category (see Figure 4). Because of the cost of grain transportation, large increases have been registered in this category of expenditures, especially over the last 3 years. The increases are being felt in the prairies and, to a lesser extent, in British Columbia. British Columbia has also received the bulk of expenditures for fruits and vegetables. In 1982-83, federal expenditures in the agri-food industry totalled $2.3 billion. Of this amount, western Canada received $1.1 billion, and Saskatchewan alone received about $552 million.

Food aid is the main component of the federal government's foreign involvement. Grain shipments capture the bulk of foreign aid expenditures, while milk powder accounts for the remainder.

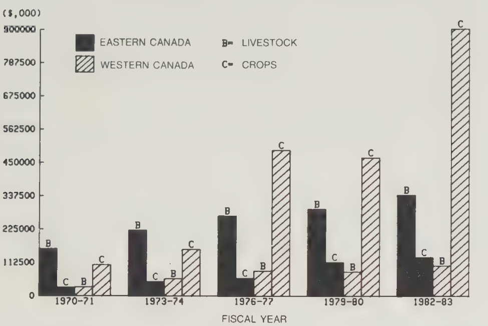
When expenditures by region and foreign aid are combined, a widening gap between expenditures on field crops and expenditures on livestock can be observed. In fact, the bulk of allocations is for grains and oilseeds.

EXPENDITURES BY CATEGORY

Federal expenditures were divided into 12 operational categories for the period 1970-71 to 1982-83. These categories cover all expenditures of Agriculture Canada and a substantial portion of the expenditures of 12 other federal departments that also contribute to the development of the Canadian agri-food industry. Four of the twelve categories alone account for nearly 70% of total expenditures. Figure 5 shows federal expenditures by category.

The leading category, direct payments through commodity programs, registered large increases until the fiscal year 1975-76. Expenditures in this category then stabilized. Approximately two-thirds of these expenditures go to the Canadian Dairy Commission in the form of subsidies to industrial milk and cream producers.

FIGURE 4 FEDERAL EXPENDITURES IN THE AGRI-FOOD SECTOR BY PRODUCT AND REGION, 1970-71 TO 1982-83



During the period, storage and freight assistance became the second major component of federal expenditures. This is mainly the result of subsidy payments for grain transportation, the purchase of railway cars, and contributions for the maintenance and rebuilding of railway branch lines on the prairies. This category contains the largest number of programs.

Technical and food aid expenditures increased from \$77.3 million in 1973-74 to \$306.7 million in 1982-83. Even though expenditures continued to rise in absolute terms, since 1978-79 their relative share has fallen. International food aid provided by the Canadian International Development Agency (CIDA) is the main item in this category.

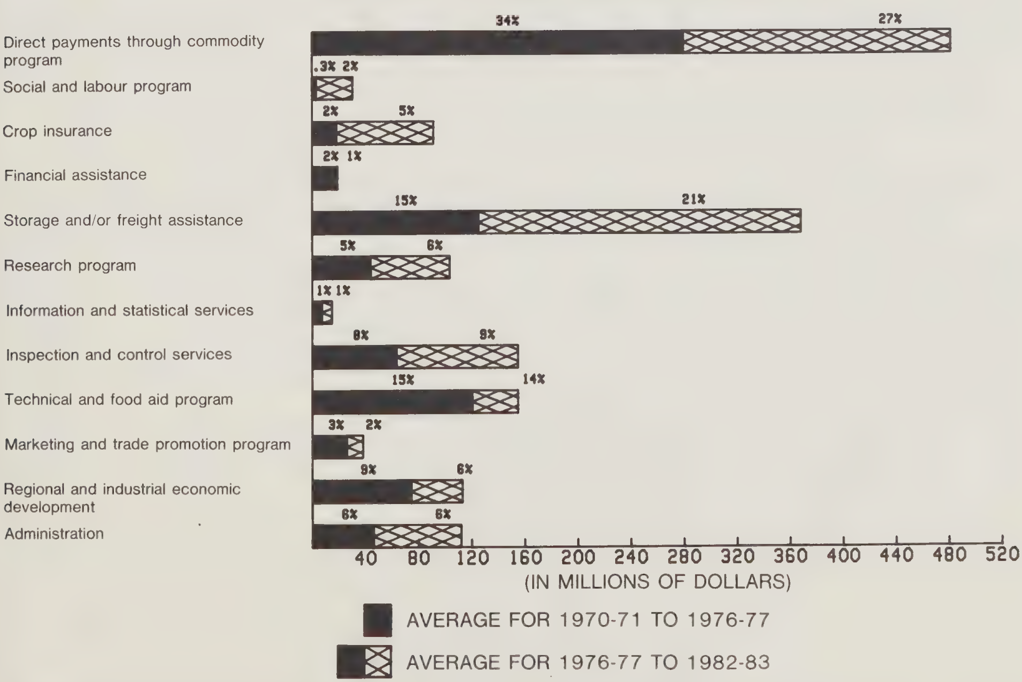
Since 1970-71, inspection and control expenditures have risen substantially, both in absolute and relative terms. The food production and inspection programs of Agriculture Canada capture about 75% of the total allocation.

The remaining categories account for 30% of the amounts allocated and are outlined below in decreasing order of importance.

Most of the regional and industrial economic development programs affecting agriculture were administered by the Department of Regional Economic Expansion (DREE). Programs such as the Agriculture and Rural Development Act (ARDA), Prairie Farm Rehabilitation Administration (PFRA) and regional development grants are the main items in this category.

Even though administration expenditures increased continually in nominal terms from 1970-71, their share of total expenditures remained constant at about 6%.

FIGURE 5 AVERAGE FEDERAL EXPENDITURES IN THE AGRI-FOOD SECTOR, BY CATEGORY, 1970-71 TO 1976-77 AND 1976-77 TO 1982-83



In recent years, agricultural research expenditures have accounted for about 6% of total federal expenditures. The Research Branch of Agriculture Canada receives about 80% of the agricultural research allocation.

Agriculture Canada contributes to the crop insurance program through payments to the provinces under federal-provincial agreements. During the period under review, the department also contributed, along with the Department of Industry, Trade and Commerce, to marketing programs.

Interest paid on amounts loaned to prairie grain growers made up the bulk of financial assistance expenditures. Financial assistance tends to vary inversely with the level of economic prosperity in agriculture.

Another category, social and labor programs, has increased slightly but still represents only a small fraction of total expenditures. Agricultural manpower and training programs, both of which are the responsibility of Employment and Immigration, are the main items in this category.

The last category, information and statistical services, is financed by Statistics Canada and Agriculture Canada. Expenditures in this category have increased in absolute terms since 1970-71, but their share has remained the same, at 1% of total federal agriculture expenditures.

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[1] Monique Rodier is an economist with the Farm Finance and Resources Division, Regional Development Branch, Agriculture Canada.

[2] Additional information on federal expenditures is available upon request to the author.

SECTION 1 TOTAL FEDERAL AGRI-FOOD EXPENDITURES BY COMMODITY AND REGION, 1970-71 TO 1982-83

TABLE 1.1 TOTAL FEDERAL AGRI-FOOD EXPENDITURES BY COMMODITY IN ATLANTIC REGION[1], 1970-71 TO 1982-83 ($'000)

Commodity	1970-71	1971-72	1972-73	1973-74	1974-75	1975-76	1976-77	1977-78	1978-79	1979-80	1980-81	1981-82	1982-83
Dairy cattle	4 636	5 025	5 274	9 578	15 431	10 350	10 884	12 835	13 484	14 837	15 290	17 281	18 024
Beef cattle	790	893	940	969	1 640	1 391	1 452	2 219	1 766	1 927	1 970	1 701	2 035
Swine	1 860	2 235	2 218	2 008	1 955	1 820	1 914	2 195	2 687	2 901	5 149	7 609	4 214
Poultry and other livestock	2 100	2 211	2 498	2 415	2 455	2 573	2 982	3 146	3 952	5 511	4 454	4 166	5 060
TOTAL LIVESTOCK AND POULTRY	9 386	10 364	10 930	14 970	21 481	16 134	17 232	20 395	21 889	25 176	26 863	30 757	29 333
Grains and oilseeds	664	710	665	756	1 052	1 447	1 499	1 681	1 735	2 315	1 803	3 878	3 431
Fruits and vegetables	5 159	6 553	6 858	7 020	7 763	18 708	11 599	12 215	24 609	24 697	20 845	26 808	22 240
Other crops	924	993	1 077	1 204	1 287	1 518	1 711	1 880	2 896	2 611	2 452	2 599	3 339
TOTAL CROPS	6 747	8 256	8 600	8 980	10 102	21 673	14 809	15 776	28 538	29 623	25 100	33 285	29 010
Unallocatable among commodities	11 555	14 374	19 019	24 910	31 532	36 357	31 021	40 379	50 850	49 883	54 617	42 984	44 041
TOTAL	27 688	32 994	38 549	48 860	63 115	74 164	63 062	76 550	101 277	104 682	106 580	107 026	102 384

[1] The Atlantic region is defined as Newfoundland, Prince Edward Island, Nova Scotia and New Brunswick

TABLE 1.2 TOTAL FEDERAL AGRI-FOOD EXPENDITURES BY COMMODITY IN CENTRAL REGION[1], 1970-71 TO 1982-83 ($'000)

Commodity	1970-71	1971-72	1972-73	1973-74	1974-75	1975-76	1976-77	1977-78	1978-79	1979-80	1980-81	1981-82	1982-83
Dairy cattle	124 510	108 760	107 391	173 748	278 834	267 220	219 393	253 455	225 143	230 365	241 334	225 150	263 381
Beef cattle	5 231	5 497	6 024	7 458	27 945	14 334	12 106	23 177	7 476	7 357	10 214	9 354	9 637
Swine	9 327	13 754	14 169	11 534	13 604	16 637	11 893	13 144	14 980	17 292	51 730	92 014	24 346
Poultry and other livestock	10 160	10 566	12 839	13 601	15 685	17 401	10 136	11 221	12 640	13 266	13 070	12 915	14 971
TOTAL LIVESTOCK AND POULTRY	149 228	138 577	140 423	206 341	336 068	315 322	253 528	300 997	260 239	268 280	316 348	369 433	312 335
Grains and oilseeds	8 442	9 570	17 331	20 572	24 615	42 263	20 593	22 108	48 570	32 397	22 147	35 183	37 973
Fruits and vegetables	7 353	8 276	8 843	10 926	12 660	19 702	16 615	14 901	23 930	25 693	23 294	44 847	31 738
Other crops	5 696	5 807	6 041	7 905	9 695	11 987	8 318	16 719	26 916	26 454	29 955	31 196	31 670
TOTAL CROPS	21 491	23 653	32 315	39 403	46 970	73 952	45 526	53 728	99 416	84 544	75 396	111 226	101 381
Unallocatable among commodities	47 732	58 603	73 480	77 111	86 118	99 061	40 360	61 528	48 084	51 831	63 791	57 911	72 683
TOTAL	218 451	220 833	246 118	322 855	469 156	488 335	339 414	416 253	407 739	404 655	455 535	538 570	486 399

[1] The central region is composed of Quebec and Ontario

TABLE 1.3 TOTAL FEDERAL AGRI-FOOD EXPENDITURES BY COMMODITY IN EASTERN REGION[1], 1970-71 TO 1982-83 ($'000)

Commodity	1970-71	1971-72	1972-73	1973-74	1974-75	1975-76	1976-77	1977-78	1978-79	1979-80	1980-81	1981-82	1982-83
Dairy cattle	129 146	113 785	112 665	183 326	294 265	277 570	230 277	266 290	238 627	245 202	256 624	272 431	281 405
Beef cattle	6 021	6 390	6 964	8 427	29 585	15 725	13 558	25 396	9 242	9 284	12 184	11 055	11 672
Swine	11 187	15 989	16 387	13 542	15 559	18 187	13 807	15 339	17 667	20 193	56 879	99 623	28 560
Poultry and other livestock	12 260	12 777	15 337	16 016	18 140	19 974	13 118	14 367	16 592	18 777	17 524	17 081	20 031
TOTAL LIVESTOCK AND POULTRY	158 614	148 941	151 353	221 311	357 549	331 456	270 760	321 392	282 128	293 456	343 211	400 190	341 668
Grains and oilseeds	9 106	10 280	17 996	21 328	25 667	43 710	22 092	23 789	50 305	34 712	23 950	39 061	41 404
Fruits and vegetables	12 512	14 829	15 701	17 946	20 423	38 410	28 214	27 116	48 537	50 390	44 139	71 655	53 978
Other crops	6 620	6 800	7 118	9 109	10 982	13 505	10 029	18 599	29 112	29 065	32 407	33 795	35 009
TOTAL CROPS	28 238	31 909	40 815	48 383	57 072	95 625	60 335	69 504	127 954	114 167	100 496	144 511	130 391
Unallocatable among commodities	59 287	72 977	92 499	102 021	117 650	135 419	71 381	101 907	98 934	101 714	118 408	100 895	116 724
TOTAL	246 139	253 827	284 667	371 715	532 271	562 500	402 476	492 803	509 016	509 337	562 115	645 596	588 783

[1] Eastern region is defined as the Atlantic region plus the central region

TABLE 1.4 TOTAL FEDERAL AGRI-FOOD EXPENDITURES BY COMMODITY IN NATIONAL CAPITAL REGION, 1970-71 TO 1982-83 ($'000)

Commodity	1970-71	1971-72	1972-73	1973-74	1974-75	1975-76	1976-77	1977-78	1978-79	1979-80	1980-81	1981-82	1982-83
Dairy cattle	–	–	–	–	–	–	7 109	193 476	32 994	35 112	25 976	22 786	13 983
Beef cattle	–	–	–	–	–	–	3 809	4 504	4 691	5 440	5 392	5 264	4 239
Swine	–	–	–	–	–	–	1 911	2 433	2 768	3 095	3 645	3 912	3 993
Poultry and other livestock	–	–	–	–	–	–	7 342	7 570	9 351	10 482	11 546	11 938	17 055
TOTAL LIVESTOCK AND POULTRY	–	–	–	–	–	–	20 171	207 983	49 804	54 129	46 559	43 900	39 270
Grains and oilseeds	–	–	–	–	–	–	10 568	10 912	10 229	11 219	12 840	13 692	15 129
Fruits and vegetables	–	–	–	–	–	–	3 552	4 352	5 445	5 367	8 114	6 952	6 099
Other crops	–	–	–	–	–	–	4 633	3 911	4 938	5 216	5 538	5 306	5 429
TOTAL CROPS	–	–	–	–	–	–	18 753	19 175	20 612	21 802	26 492	25 950	26 657
Unallocatable among commodities	–	–	–	–	–	–	74 103	73 791	85 409	94 195	118 745	138 999	152 166
TOTAL	–	–	–	–	–	–	113 027	300 949	155 825	170 126	191 796	208 849	218 093

TABLE 1.5 TOTAL FEDERAL AGRI-FOOD EXPENDITURES BY COMMODITY IN WESTERN REGION[1], 1970-71 TO 1982-83 ($'000)

Commodity	1970-71	1971-72	1972-73	1973-74	1974-75	1975-76	1976-77	1977-78	1978-79	1979-80	1980-81	1981-82	1982-83
Dairy cattle	15 526	16 174	17 817	38 089	61 322	45 852	42 881	47 910	46 613	45 176	47 397	50 314	49 439
Beef cattle	7 070	7 703	8 750	10 199	40 307	27 651	28 448	67 972	23 533	20 603	23 735	23 941	28 396
Swine	3 519	9 317	7 556	4 833	6 511	5 854	5 270	5 721	7 195	6 730	21 274	41 336	11 851
Poultry and other livestock	3 857	4 101	5 311	5 005	6 418	7 130	7 992	7 866	8 942	9 249	13 316	12 067	12 618
TOTAL LIVESTOCK AND POULTRY	29 972	37 295	39 434	58 126	114 558	86 487	84 591	129 469	86 283	81 758	105 722	127 658	102 304
Grains and oilseeds	93 969	155 796	177 924	142 860	206 040	369 793	460 171	330 291	408 965	440 662	533 950	629 942	863 103
Fruits and vegetables	4 780	5 271	6 014	6 732	7 521	8 454	17 020	15 577	13 452	13 359	15 110	23 219	20 860
Other crops	6 071	6 346	6 715	7 935	10 284	13 791	14 557	13 284	13 383	13 274	15 350	15 187	18 753
TOTAL CROPS	104 820	167 413	190 653	157 527	223 845	392 038	491 748	359 152	435 800	467 225	564 410	668 348	902 716
Unallocatable among commodities	36 611	31 948	43 983	50 619	75 870	62 223	70 020	88 662	82 854	82 415	145 219	123 733	121 840
TOTAL	171 403	236 656	274 070	266 272	414 273	540 748	646 359	577 283	604 937	631 428	815 351	919 739	1 126 860

[1] The western region is defined as the prairies plus British Columbia

TABLE 1.6 TOTAL FEDERAL AGRI-FOOD EXPENDITURES BY COMMODITY OUTSIDE CANADA, 1970-71 TO 1982-83 ($'000)

Commodity	1970-71	1971-72	1972-73	1973-74	1974-75	1975-76	1976-77	1977-78	1978-79	1979-80	1980-81	1981-82	1982-83
Dairy cattle	11 006	1 726	7 062	1 614	12 499	8 021	14 072	18 639	13 059	8 769	10 118	12 780	16 627
Beef cattle	–	–	–	–	–	5 494	–	762	305	–	–	–	–
Swine	–	–	–	–	–	–	–	–	–	–	–	–	–
Poultry and other livestock	–	675	1 226	–	791	1 062	518	514	839	428	149	–	242
TOTAL LIVESTOCK AND POULTRY	11 006	2 401	8 288	1 614	13 290	14 577	14 590	19 915	14 203	9 197	10 267	12 780	16 869
Grains and oilseeds	89 761	75 331	85 777	70 478	98 734	203 547	223 121	188 997	169 329	173 141	167 600	195 584	232 731
Fruits and vegetables	113	430	35	–	–	–	1 918	–	–	228	–	–	762
Other crops	303	699	527	68	1 392	1 192	162	2 073	2 896	3 274	2 129	3 763	4 183
TOTAL CROPS	90 177	76 460	86 339	70 546	100 126	204 739	225 201	191 070	172 225	176 643	169 729	199 347	237 676
Unallocatable among commodities	8 121	6 950	9 371	11 728	16 780	27 774	22 259	58 607	51 095	55 040	48 643	66 814	63 704
TOTAL	109 304	85 811	103 998	83 888	130 196	247 090	262 050	269 592	237 523	240 880	228 639	278 941	318 249

TABLE 1.7 GRAND TOTAL OF FEDERAL AGRI-FOOD EXPENDITURES BY COMMODITY 1970-71 TO 1982-83 ($'000)

Commodity	1970-71	1971-72	1972-73	1973-74	1974-75	1975-76	1976-77	1977-78	1978-79	1979-80	1980-81	1981-82	1982-83
Dairy cattle	155 678	131 685	137 544	223 029	368 086	331 443	294 339	526 315	331 293	334 259	340 115	358 311	361 454
Beef cattle	13 091	14 093	15 714	18 626	69 892	48 870	45 815	98 634	37 771	35 327	41 311	40 260	44 307
Swine	14 706	25 306	23 943	18 375	22 070	24 041	20 988	23 493	27 630	30 018	81 798	144 781	44 404
Poultry and other livestock	16 117	17 553	21 874	21 021	25 349	28 166	28 970	30 317	35 724	38 936	42 535	41 086	49 946
TOTAL LIVESTOCK AND POULTRY	199 592	188 637	199 075	281 051	485 397	432 520	390 112	678 759	432 418	438 540	505 759	584 528	500 111
Grains and oilseeds	196 259	242 950	287 728	240 736	338 748	630 393	729 726	581 740	664 348	694 423	774 411	912 861	1 183 283
Fruits and vegetables	17 405	20 530	21 750	24 678	27 944	46 864	50 704	47 045	67 434	69 344	67 363	101 826	81 699
Other crops	12 994	13 845	14 360	17 112	22 658	28 488	29 381	37 867	50 329	50 829	55 424	58 051	63 374
TOTAL CROPS	226 658	277 325	323 838	282 526	389 350	705 745	809 811	666 652	782 111	814 596	897 198	1 072 738	1 328 456
Unallocatable among commodities	104 019	111 875	145 853	164 368	210 300	225 416	237 763	322 967	318 292	333 364	431 015	430 441	454 434
TOTAL	530 269	577 837	668 766	727 945	1 085 047	1 363 681	1 437 686	1 668 378	1 532 821	1 586 500	1 833 972	2 087 707	2 283 001

TABLE 1.8 FEDERAL AGRI-FOOD EXPENDITURES BY DEPARTMENT, 1970-71 TO 1982-83 ($'000)

	1970-71	1971-72	1972-73	1973-74	1974-75	1975-76	1976-77	1977-78	1978-79	1979-80	1980-81	1981-82	1982-83
External Affairs	107 127	82 792	101 298	77 276	117 711	236 253	253 587	261 609	224 164	223 369	210 532	256 056	306 221
Indian and Northern Affairs	862	1 076	1 169	857	1 833	2 285	2 615	2 240	3 838	5 186	3 355	5 983	6 383
Agriculture Canada	277 006	286 095	312 857	426 420	664 281	651 092	630 259	958 580	767 963	781 870	881 531	1 124 603	1 010 244
Supply and Services	2 200	3 400	2 600	2 600	2 800	3 400	6 000	4 800	5 600	5 000	5 600	8 800	7 900
Employment and Immigration	151	153	250	240	2 034	3 462	3 924	17 473	19 804	28 910	38 705	37 591	42 644
Energy Mines and Resources	0	0	0	0	0	0	0	0	0	814	1 446	2 140	2 112
Environment	0	0	582	927	1 339	1 000	826	1 500	585	479	700	479	625
Regional Economic Expansion	49 821	51 081	64 019	68 125	83 559	91 183	91 561	106 473	111 866	99 344	153 602	101 836	81 280
Finance	0	0	0	0	74	0	0	0	0	0	0	0	0
Industry – Commerce	56 719	105 063	142 877	87 984	106 521	250 096	318 426	111 786	131 953	138 899	151 265	140 209	150 456
Health and Welfare	1 834	2 214	3 239	6 606	9 093	11 002	13 520	13 930	14 227	15 621	25 929	22 936	26 527
Science and Technology	3 557	4 004	4 807	5 787	6 580	8 258	9 741	11 271	12 851	16 900	19 903	22 793	26 237
Transport	30 992	41 969	35 068	51 122	89 222	105 650	107 227	178 722	239 947	269 539	341 402	364 278	622 371
Labour	0	0	0	0	0	0	0	0	21	16	0	0	0
TOTAL	530 269	577 847	668 766	727 944	1 085 047	1 363 681	1 437 686	1 668 384	1 532 819	1 585 947	1 833 970	2 087 704	2 283 000

SECTION 2 LIST OF PROGRAMS AND ACTIVITIES BY CATEGORY AND DEPARTMENT 1970-71 TO 1982-83

The expenditures presented in Section 1 by province and commodity are presented by program in this section. The programs have been classified into 12 functional categories. In the tables, a symbol after each program number indicates the type of expenditure made under the program. The symbols used are:

– Grants and contributions only
+ Grants and contributions including operating and capital expenditures

After each program name, the abbreviation for the responsible department is given. The abbreviations used are:

AG	—Agriculture
DREE	—Department of Regional Economic Expansion
DSS	—Department of Supply and Services
E&I	—Employment and Immigration
EM&R	—Energy, Mines and Resources
ENV	—Environment
EXT AFF	—External Affairs
FIN	—Finance
IA&ND	—Indian Affairs and Northern Development
IT&C	—Industry, Trade and Commerce
LAB	—Labour
NH&W	—National Health and Welfare
S&T	—Science and Technology
T	—Transport

LIST OF PROGRAMS AND ACTIVITIES, 1970-71 TO 1982-83 ($'000)

	Programs Department	1970-71	1971-72	1972-73	1973-74	1974-75	1975-76	1976-77	1977-78	1978-79	1979-80	1980-81	1981-82	1982-83
2.1	**Direct Payments through Commodity Programs:**													
2.1.1 –	Payments to the Canadian Dairy Commission (CDC) for Subsidies to Producers of Industrial Milk & Cream (AG.)	125 000	109 000	107 400	143 400	251 100	275 000	233 118	293 580	271 524	279 695	287 918	301 500	295 000
2.1.2 –	Deficiency Payments to Producers by Agricultural Stabilization Board (AG.)	1 395	12 985	11 184	97	46 474	25 840	28 748	70 531	47 039	30 235	47 806	137 718	6 131
2.1.3 –	Price Support Agricultural Products Board (AG.)	398	520	419	5	98	415	1 122	35	107	149	9 312	3 153	10 174
2.1.4 –	Quality Premium on Hog and Lamb Carcasses (AG.)	1 379	–		–		–	–	–		–	–	–	–
2.1.5 –	Subsidies on Fluid Milk and Powder (AG.)	–	–	–	51 474	74 621	14 453	13 080	12 952	563	–	–	–	–
2.1.6 –	Grassland Incentive Payments (AG.)	–	–	–	5 355	14 944	–	–	–	–	–	–	–	–
2.1.7 –	Two-Price Wheat (IT&C)	–	–	63 173	69 386	81 230	188 698	65 303	21 860	43 826	16	–	–	–
2.1.8 –	Contributions to the Western Grain Stabilization Program (IT&C)	–	–	–	–	–		61 801	57 980	53 157	95 559	119 416	94 320	114 906
2.1.9 –	Payments to Wheat Producers to Increase Minimum Return (IT&C)	–	–	–	–	–	–	–	4,500	405	–	-		–
2.1.10 –	Compensation to Provinces for Crop Damages Caused by Migratory Waterfowl (AG.)	–	–	–	–	–	–	–	–	1 500	1 131	1 823	594	797
2.1.11 –	Contributions to Provinces for Waterfowl Crop Depredation (ENV.)	–	–	582	927	1 339	1 000	826	1 500	585	479	700	479	625
2.1.12 –	Write-off of Canadian Dairy Commission (CDC) Milk Powder Export Subsidy Deficit (AG.)	–	–	–	–	–		–	159 718	–	–	–	–	–
2.1.13 –	Compensation in Accordance with the Terms of the Plant Quarantine Act & Regulations (AG.)	–	–	–	–	–	–	–	–	1	–		–	712
2.1.14 –	Contributions to Producers for Losses Due to the Canadian Embargo on Grain Sales to USSR (AG.)	–	–	–	–	–		–	–	–		–	79 245	50
2.1.15 –	Contributions to Canadian Wheat Board for Sales of Feed Grains at Corn Competitive Price (AG.)	–	–	–	–	–	–	–			–	–	–	8 000
Sub-Total		**128 172**	**122 505**	**182 758**	**270 644**	**469 806**	**505 406**	**403 998**	**622 656**	**418 707**	**407 264**	**466 975**	**617 009**	**436 195**

(continued)

LIST OF PROGRAMS AND ACTIVITIES, 1970-71 TO 1982-83 ($'000) (Continued)

	Programs Department	1970-71	1971-72	1972-73	1973-74	1974-75	1975-76	1976-77	1977-78	1978-79	1979-80	1980-81	1981-82	1982-83
2.2	**Social and Labour Programs:**													
2.2.1 –	Canada West Foundation (IT&C)	–	–	–	–	–	–	–	–	75	–	–	–	–
2.2.2 –	Exhibition Contributions (AG.)	1 342	1 359	1 378	1 405	1 411	1 470	1 596	1 646	2 011	1 965	2 152	2 212	2 297
2.2.3 –	Agricultural Museum Contributions (AG.)	21	24	24	24	24	30	31	31	31	–	–	–	–
2.2.4 –	Federated Women's Institutes of Canada (AG.)	10	10	10	10	10	10	10	10	10	10	10	10	20
2.2.5 –	4-H Club Assistance (AG.)	191	193	198	208	196	208	212	216	221	207	217	217	276
2.2.6 –	Farm Labour Pool (E&I)	151	153	250	240	1 984	3 462	3 438	3 804	3 811	4 063	4 259	4 332	5 610
2.2.7 –	Canada Manpower Mobility Program: Seasonal Agricultural Employment (E&I)	–	–	–	–	–	–	486	822	956	905	755	1 507	1 741
2.2.8 –	Agriculture for Young Canadians (E&I)	–	–	–	–	50	–	–	75	–	–	–	–	–
2.2.9 –	Student Summer Employment and Activities (AG.)	–	–	–	–	–	–	–	682	908	2 921	1 990	1 052	1 194
2.2.10 –	General Industrial Training Programs (E&I)	–	–	–	–	–	–	–	6 266	7 683	7 791	9 521	8 372	5 641
2.2.11 –	Activities Complementary to the Labour Market (E&I)	–	–	–	–	–	–	–	2 954	2 721	2 626	6 450	5 604	5 258
2.2.12 –	Providing Employment to Unemployed Workers (E&I)	–	–	–	–	–	–	–	3 552	4 633	1 688	2 353	1 720	2 899
2.2.13 –	Institutional Training Program (E&I)	–	–	–	–	–	–	–	–	–	11 837	15 367	16 056	18 944
2.2.14 –	Federal Labour Intensive Program (IT&C)	–	–	–	–	–	–	–	–	73	–	–	–	–
2.2.15 –	Critical Trade Skills Training (E&I)	–	–	–	–	–	–	–	–	–	–	–	–	2 551
Sub-Total		**1 715**	**1 739**	**1 860**	**1 887**	**3 675**	**5 180**	**5 773**	**20 058**	**23 133**	**34 013**	**43 074**	**41 082**	**46 431**
2.3	**Crop Insurance:**													
2.3.1 –	Contributions to Provinces under the Crop Insurance Act (AG.)	2 898	3 158	4 144	15 182	31 140	48 276	56 457	72 812	74 965	78 097	100 132	115 850	142 191
2.3.2 –	Contribution to Province of Quebec for an Experimental Crop Insurance Program (AG.)	920	877	1 070	1 473	96	–	–	–	–	–	–	–	–
Sub-Total		**3 818**	**4 035**	**5 214**	**16 655**	**31 236**	**48 276**	**56 457**	**72 812**	**74 965**	**78 097**	**100 132**	**115 850**	**142 191**
2.4	**Financial Assistance:**													
2.4.1 –	Farm Credit Corporation Net Loss (AG.)	8 603	8 885	8 446	6 808	4 716	3 514	2 400	1 700	–	–	–	–	–
2.4.2 –	Pesticide Residue Compensation (AG.)	–	–	–	–	13	1	–	–	–	–	–	–	–
2.4.3 –	Prairie Grain Provisional Payments (IT&C)	63	21	10	8	42	–	–	–	–	–	–	–	–
2.4.4 –	Prairie Grain Advance Payments (IT&C)	11 614	3 513	1 036	1 645	3 058	1 011	2 550	3 478	5 193	6 394	2 710	12 735	11 621
2.4.5 –	Deficit Pool Accounts (IT&C)	18 295	11 210	3 870	–	–	–	–	–	–	–	1 828	–	–
2.4.6 –	Deletion from the Accounts of Advances made to Saskatchewan to Provide Seed Grain Loans to Farmers (FIN.)	–	–	–	–	74	–	–	–	–	–	–	–	–
2.4.7 –	Interest Payments and Guarantees under the Advance Payments for Crops Act (AG.)	–	–	–	–	–	–	–	252	724	1 951	3 876	7 748	6 932
2.4.8 –	Loan Guarantees under the Farm Improvement Loans Act (AG.)	–	–	–	–	–	–	–	–	288	397	626	539	1 343
2.4.9 –	Contribution to Weanling Pig Producers $1.00 per Piglet Sold for the Fiscal Year 1979-80 (AG.)	–	–	–	–	–	–	–	–	–	–	4 357	–	–
2.4.10 –	Financial Assistance to Livestock Producers in Drought Areas (AG.)	–	–	–	–	–	–	–	–	–	–	3 705	102	–
2.4.11 –	Emergency Herd Maintenance Assistance Program (AG.)	–	–	–	–	–	–	–	–	–	–	748	13	–
2.4.12 –	Emergency Herd Maintenance Assistance Program (DREE)	–	–	–	–	–	–	–	–	–	–	42 887	2 093	–

(continued)

LIST OF PROGRAMS AND ACTIVITIES, 1970-71 TO 1982-83 ($'000) (Continued)

	Programs Department	1970-71	1971-72	1972-73	1973-74	1974-75	1975-76	1976-77	1977-78	1978-79	1979-80	1980-81	1981-82	1982-83
2.4.13 –	Contribution to Greenhouse Operator to Cover Interest Costs (AG.)	–	–	–	–	–	–	–	–	28	19	21	–	–
2.4.14 –	Contribution of 50% of Defaulted Loans pursuant to the 1972 Adverse Weather Assistance Program (AG.)	–	–	–	–	–	–	42	–	12	53	–	–	–
2.4.15 –	Contribution of 50% of the Unpaid Principal to Farmers affected by Flooding in the Peace River Area (AG.)	–	–	–	–	–	–	–	–	17	–	–	–	–
2.4.16 –	Payments of 50% of the Cost of Assistance to Potato Producers for Closure of Spetifore Frozen Food Ltd (AG.)	–	–	–	–	–	–	–	–	152	–	–	–	–
2.4.17 –	Payments to Producers Unable to seed their Agricultural Lands due to Adverse Weather (AG.)	–	–	–	699	795	3	–	–	–	–	–	–	–
2.4.18 –	Grants to Farmers in Designated Areas who have Experienced Crop Losses due to Adverse Weather (AG.)	–	–	12 250	1 244	–	–	–	–	–	–	–	–	–
2.4.19 –	Grants to Maritime Provinces to Re-establish Strawberry Acreage due to 1971-72 Winter Kill (AG.)	–	–	–	78	–	–	–	–	–	–	–	–	–
2.4.20 –	Farm Loans Interest Rebates (AG.)	–	–	–	–	–	–	–	–	–	–	–	–	3 426
Sub-Total		**38 575**	**23 629**	**25 612**	**10 482**	**8 698**	**4 529**	**4 992**	**5 430**	**6 414**	**8 814**	**60 758**	**23 230**	**23 322**
2.5	**Storage and/or Freight Assistance:**													
2.5.1 +	Feed Freight Assistance Program (AG.)	20 773	20 563	21 381	22 737	21 921	20 709	12 730	11 773	14 155	18 070	18 016	17 504	15 479
2.5.2 –	Freight on Livestock Shipment to Royal Winter Fair (AG.)	46	63	61	40	28	65	114	64	99	83	93	94	110
2.5.3 +	Canadian Government Elevator Operations (AG.)	2 478	3 132	3 671	4 050	6 357	8 126	7 968	7 399	10 262	9 486	2 149	87	–
2.5.4 –	Payments of 50% of the Cost of Transportation of Fodder Hay and Silage due to Adverse Weather or Drought Conditions (AG.)	–	–	580	820	944	1 401	2 599	354	591	–	2 428	–	–
2.5.5 –	Contributions to Producer Groups towards the Cost of Construction of Cold Storage (AG.)	–	–	–	367	1218	1 292	893	1 645	1 808	3 040	2 713	3 048	3 000
2.5.6 –	Payments on Temporary Wheat Reserves (IT&C)	23 650	86 553	21 919	5 833	–	–	–	–	–	–	–		–
2.5.7 –	Payments to Canadian Wheat Board for the Purchase and / or Leasing of Hopper Cars to Transport Grains (IT&C)	–	–	46 091	–	–	40 639	167 341	2 343	838	–	–	–	–
2.5.8 –	Contribution to CN and CP for Leasing Railway Cars (IT&C)	–	–	1 300	–	3 430	–	–	–	–	–	–	–	–
2.5.9 –	Contribution to Wheat Board to Cover Carrying Charges on Reserve Stock of Feed Grains (IT&C)	–	–	–	–	1 849	3 215	2 743	2 994	2 200	2 200	733	–	–
2.5.10 –	Contribution to Railways under Section 258 of Railway Act (T.)	23 364	35 414	22 931	37 537	71 713	82 379	82 410	109 498	130 261	149 332	203 577	221 233	258 941
2.5.11 –	Contribution to Railways under Section 272 of Railway Act (T.)	3 423	1 543	6 031	6 070	8 307	13 343	13 774	27 751	25 520	34 729	36 071	34 582	31 016
2.5.12 –	Maritime Freight Rates Act & Atlantic Region Freight Assistance Act (T.)	4 205	5 012	6 106	7 515	9 202	9 928	11 043	11 473	14 166	15 132	15 211	16 887	16 362
2.5.13 –	Assistance to Rapeseed Processing Freight (IT&C)	–	–	–	–	–	–	500	2 500	3 839	3 000	3 000	3 000	3 000
2.5.14 –	Feed Freight Assistance Adjustment Fund (AG.)	–	–	–	–	–	–	–	4 996	11 749	9 976	10 330	9 215	2 477
2.5.15 –	Canadian Cooperative Implements Ltd. (AG.)	–	–	–	–	–	–	–	8 000	–	–	–	6 438	2 000

(continued)

	Programs Department	1970-71	1971-72	1972-73	1973-74	1974-75	1975-76	1976-77	1977-78	1978-79	1979-80	1980-81	1981-82	1982-83
2.5.16 –	Assistance to United Cooperatives of Ontario (UCO) Grain Terminal (AG.)	–	–	–	–	–	–	500	8 000	–	500	–	–	–
2.5.17 –	Rehabilitation of Boxcars (IT&C)	–	–	–	–	–	–	–	–	2 911	8 044	–	650	–
2.5.18 –	Rehabilitation of Prairie Branch Railway Lines (T.)	–	–	–	–	–	–	–	30 000	70 000	70 000	70 000	77 000	84 700
2.5.19 –	Contribution towards the Cost of Transportation of Apples for Apple Juice (AG.)	–	–	–	–	–	–	–	–	–	–	273	–	–
2.5.20 –	Contribution to the Task Force on Explosions and Fire Hazards in Grain Elevators (LAB.)	–	–	–	–	–	–	–	–	21	16	–	·	–
2.5.21 –	Payments to the National Harbour Board for the Construction of Grain Handling Facilities in Prince Rupert (T.)	–	–	–	–	·	–	–	–	–	30	2 700	–	–
2.5.22 –	Payments to CN and CP for Railway Cars (T.)	–	–	–	–	–	–	–	–	–	–	4 215	133	–
2.5.23 –	Contribution to Elevator Operators for Expansion in Feed Grain Deficient Areas of Eastern Canada (AG.)	–	–	–	–	–	–		·	240		–	–	–
2.5.24 –	Grain Transportation Administration (T.)	–	–	–		–	–	–	–	–	316	952	2 443	1 890
2.5.25 –	Payments to Canadian Wheat Board for the Purchase and/or Leasing of Hopper Cars to Transport Grains (T.)	–	–	–	–	–	–	–	–	–	–	8 676	12 000	99 062
2.5.26 –	Contributions to Railways for Revenue Losses incurred during 1982-83 Crop Year (T.)	–	–	–	–	–	–	–	–	–	–	–	–	130 400
2.5.27 –	Propane Vehicle Program-Farm Vehicle Conversion (EM&R)	–	–	–	–	–	–	–	–	–	–	12	98	362
Sub-Total		**77 939**	**152 280**	**130 071**	**84 969**	**124 969**	**181 097**	**302 615**	**228 790**	**288 660**	**323 954**	**381 149**	**404 412**	**648 799**
2.6.	**Research Programs:**													
2.6.1 +	Research Activities (AG.)	28 967	31 128	33 730	37 178	41 714	47 878	52 044	58 918	64 172	68 761	82 838	108 982	138 810
2.6.2 –	Livestock Improvement (AG.)	22	21	16	33	33	50	91	121	113	–	–	–	–
2.6.3 –	New Crop Development Fund (AG.)	–	–	–	–	100	521	759	913	737	626	732	726	741
2.6.4 –	Research: Canadian Dairy Commission (AG.)	–	–	·	–	–	–	–	261	760	651	342	1 476	1 694
2.6.5 –	Industrial Research Assistance Program (S&T)	–	–	–	973	1 833	2 542	2 806	3 201	3 955	4 697	4 648	5 158	5 650
2.6.6 +	Grain Testing and Research (AG.)	928	1 090	1 336	1 682	1 997	2 058	2 224	2 743	2 747	2 835	2 883	2 780	3 832
2.6.7 –	Operating Grants for Research (S&T)	1 927	2 465	3 010	2 929	2 558	3 299	3 812	4 345	4 760	4 804	6 419	6 718	9 006
2.6.8 –	Strategic Grants for Research (S&T)	–	–	–	–	–	–	–	–	–	2 305	3 164	4 584	4 305
2.6.9 –	Plant Biotechnology Institute (S&T)	1 630	1 539	1 797	1 885	2 189	2 417	3 123	3 725	4 136	5 094	5 672	6 333	7 276
Sub-Total		**33 474**	**36 243**	**39 889**	**44 680**	**50 424**	**58 765**	**64 859**	**74 227**	**81 380**	**89 773**	**106 698**	**136 757**	**171 314**
2.7	**Information and Statistical Services:**													
2.7.1 +	Canfarm (AG.)	–	–	–	–	–	5 296	5 565	6 022	–	1 200	5 993	1 000	–
2.7.2 +	Information (AG.)	1 472	1 952	2 299	2 202	2 679	2 765	3 263	3 422	4 105	3 685	4 382	3 307	3 929
2.7.3 +	Elevator and Grain Documentation (AG.)	708	905	1 029	1 117	1 303	1 407	1 604	1 722	1 850	1 893	2 247	1 720	2 324
2.7.4 –	Canadian National Livestock Records (AG.)	50	50	50	65	50	50	50	50	50	50	50	50	50
2.7.5 +	Statistics Canada: Agriculture Statistics Division (DSS)	2 200	3 400	2 600	2 600	2 800	3 400	6 000	4 800	5 600	5 000	5 600	8 800	7 900
Sub-Total		**4 430**	**6 307**	**5 978**	**5 984**	**6 832**	**12 918**	**16 482**	**16 016**	**11 605**	**11 828**	**18 272**	**14 877**	**14 203**

(continued)

	Programs Department	1970-71	1971-72	1972-73	1973-74	1974-75	1975-76	1976-77	1977-78	1978-79	1979-80	1980-81	1981-82	1982-83
2.8	**Inspection and Control Services:**													
2.8.1 +	Grain Inspection (AG.)	4 024	4 861	5 824	5 921	6 601	7 886	8 190	8 213	9 137	10 525	10 741	11 995	15 193
2.8.2 +	Food Quality & Hazards (NH&W)	1 834	2 214	3 239	6 606	9 093	11 002	13 520	13 930	14 227	15 621	25 929	22 936	26 527
2.8.3 +	Grain Weighing (AG.)	2 147	2 581	2 702	2 541	2 724	3 539	3 635	3 727	5 065	5 356	6 100	6 496	8 163
2.8.4 +	Race Track Supervision Revolving Fund (AG.)	–	–	–	–	–	–	–	–	–	–	889	161	1 524
2.8.5 +	Food Production And Inspection Programs (AG.)	32 522	37 893	43 096	48 526	59 292	74 575	84 824	92 971	122 354	119 156	126 497	129 443	161 339
Sub-Total		**40 527**	**47 549**	**54 861**	**63 594**	**77 710**	**97 002**	**110 169**	**118 841**	**150 783**	**150 658**	**170 156**	**171 031**	**212 746**
2.9	**Technical and Food Aid Programs:**													
2.9.1 –	World Food Program (EXT.AFF.)	4 023	3 323	3 279	3 739	3 612	10 249	–	10 000	10 000	10 000	12 692	11 000	13 600
2.9.2 +	International Food Aid Program (EXT.AFF.)	99 551	76 529	93 964	66 164	103 479	211 397	235 212	219 822	174 087	170 072	166 276	205 087	244 213
2.9.3 –	FAO (EXT.AFF.)	2 481	1 538	1 528	2 227	2 291	3 524	3 573	4 701	4 840	6 747	6 476	8 430	8 705
2.9.4 –	Mennonite Central Committee Food Bank (EXT.AFF.)	–	–	–	–	–	–	–	500	2 335	3 323	1 500	2 000	6 567
2.9.5 –	Membership Fees and Contributions to International Organizations (EXT.AFF.)	572	761	935	1 904	2 867	3 136	4 178	18 226	21 337	21 856	9 624	13 406	15 053
2.9.6 –	International Development Research Centre : Program on Agriculture Food and Nutrition Science (EXT.AFF.)	500	641	1 592	3 242	5 462	7 947	10 624	8 360	11 565	11 285	12 846	14 206	15 472
2.9.7 –	Contributions in Support of Joint Federal-Provincial Voluntary Agricultural Development Projects (EXT.AFF.)	–	–	–	–	–	–	–	–	–	–	1 000	1 212	1 372
2.9.8 +	International Development Assistance (AG.)	–	–	–	–	–	–	–	–	–	–	–	1 460	1 747
Sub-Total		**107 127**	**82 792**	**101 298**	**77 276**	**117 711**	**236 253**	**253 587**	**261 609**	**224 164**	**223 283**	**210 414**	**256 801**	**306 729**
2.10	**Marketing and Trade Promotion Programs:**													
2.10.1 +	Marketing and Economics (AG.)	11 509	15 421	17 042	19 145	22 308	19 604	22 415	26 090	11 381	11 460	13 109	9 136	11 870
2.10.2 –	Rapeseed Utilization Assistance (IT&C)	200	200	300	300	300	300	325	325	350	350	375	375	400
2.10.3 –	Grains Export Credit (IT&C)	1 599	2 291	2 106	5 946	11 904	10 070	7 743	7 218	12 399	16 476	16 589	21 788	11 054
2.10.4 –	Grains & Oilseeds Marketing Incentives (IT&C)	–	–	726	318	412	390	635	979	840	471	288	103	–
2.10.5 –	Contribution to the Canadian International Grains Institute (IT&C)	–	–	–	564	355	443	529	619	686	786	822	963	1 077
2.10.6 –	Payments to Western Millers re. Stop-off Charges (IT&C)	–	–	–	39	133	200	725	850	983	1 058	818	851	656
2.10.7 +	Marketing (IT&C)	–	–	1 032	1 294	1 426	2 539	2 460	1 928	1 783	1 653	2 009	2 700	3 138
2.10.8 +	Milk Promotion by Canadian Dairy Commission (AG.)	–	–	–	–	–	–	500	2 696	3 856	4 500	2 100	–	–
2.10.9 –	Grants and Scholarship to Assist Up-Grading of Technological Capability in the Food Industry (IT&C)	10	15	15	15	15	15	15	15	15	15	15	15	15
2.10.10 –	International Wheat Council (IT&C)	33	38	38	49	58	100	107	121	160	215	266	237	245
2.10.11 –	Canada Grains Council (IT&C)	69	50	47	50	50	60	60	60	60	60	60	86	90
2.10.12 –	Canada Grains Council (AG.)	69	50	47	50	50	60	60	60	60	60	54	92	90
2.10.13 –	POS Pilot Plant (IT&C)	–	–	–	25	35	644	3 172	1 672	744	1 036	641	600	600
2.10.14 –	Contributions for the Purpose of Expanding the Total Markets for Agricultural Products Other Than Grains and Oilseeds (IT&C)	–	–	20	706	700	532	643	541	444	363	499	158	12

(continued)

LIST OF PROGRAMS AND ACTIVITIES, 1970-71 TO 1982-83 ($'000) (Concluded)

	Programs Department	1970-71	1971-72	1972-73	1973-74	1974-75	1975-76	1976-77	1977-78	1978-79	1979-80	1980-81	1981-82	1982-83
2.10.15 –	Membership Fees and Contributions to International Organizations (IT&C)	68	74	66	83	77	–	–	116	120	188	125	142	–
2.10.16 –	Contribution to Canadian Turkey Processing Industry (AG.)	–	–	–	–	–	–	–	–	–	–	3 750	363	–
2.10.17 –	Membership Fees and Contributions to International and Domestic Organizations (AG.)	8	8	8	26	39	33	39	33	41	45	63	42	56
2.10.18 –	Program for Export Market Development (EXT.AFF.)	–	–	–	–	–	–	–	–	–	86	118	715	1 239
2.10.19 –	Contribution to Promote the Sale of Canadian Seed Potatoes (AG.)	–	–	–	–	–	–	–	–	–	–	–	–	76
Sub-Total		**13 565**	**18 147**	**21 447**	**28 710**	**37 862**	**34 990**	**39 428**	**43 323**	**33 922**	**38 822**	**41 701**	**38 366**	**30 618**
2.11	**Regional & Industrial Economic Development:**													
2.11.1 –	Agricultural and Rural Development Act-ARDA-(DREE)	18 088	14 518	21 310	24 837	32 243	31 857	31 679	26 006	24 725	12 912	13 494	14 851	9 655
2.11.2 –	Comprehensive Rural Economic Development (DREE)	4 130	5 213	6 296	7 261	7 292	7 149	3 050	–	–	–	–	–	–
2.11.3 –	Land Inventory (ENV. & DREE)	4 016	3 272	1 878	698	416	76	–	–	–	–	–	–	–
2.11.4 –	Comprehensive Development Plan for Prince Edward Island (DREE)	649	953	1 803	3 029	4 133	4 718	6 268	8 698	9 963	8 048	8 999	5 241	4 775
2.11.5 –	Prairie Farm Rehabilitation Adminis-tration-PFRA-(DREE)	14 545	14 817	23 940	22 551	27 727	26 672	26 177	35 327	32 588	27 783	37 056	41 607	44 225
2.11.6 –	Agricultural Subsidiary Agreements (DREE)	–	–	–	–	1 043	8 986	14 529	18 709	23 672	33 838	31 600	21 703	–
2.11.7 –	Agricultural Subsidiary Agreements (AG.)	–	-	–	–	–	–	–	–	-	–	–	–	16 653
2.11.8 –	Contributions to Indians and Inuits for Economic Development and Employment in Agriculture (IA&ND)	862	1 076	1 169	857	1 833	2 285	2 615	2 240	3 838	5 186	3 355	5 983	6 383
2.11.9 –	Contribution to the Federal Development Strategy for Prince Edward Island (AG.)	–	–	–	–	–	–	–	–	–	–	–	142	824
2.11.10 +	Small Farm Development Adjustment (AG.)	–	–	638	6 102	8 653	7 318	6 548	4 383	2 107	17	9	1	–
2.11.11 –	Regional Development Incentives (DREE)	8 393	12 308	8 792	9 749	10 705	11 725	9 858	17 733	20 918	16 763	19 566	16 341	22 625
2.11.12 –	Industry Development (IT&C)	1 118	1 098	1 128	1 623	1 447	1 240	1 774	1 687	852	1 015	1 071	1 486	3 642
2.11.13 –	Economic Growth Components of Canada Works (EM&R)	–	–	–	–	–	–	–	–	–	455	–	–	–
2.11.14 –	Conservation and Renewable Energy Demonstration Agreements-CREDA-(EM&R)	–	–	–	–	–	–	–	–	–	359	1 434	2 042	1 563
2.11.15 –	Forest Industry Renewable Energy-Fire-Program (EM&R)	–	–	–	–	–	–	–	–	–	–	–	–	187
2.11.16 +	Regional Development (AG.)	–	–	–	–	–	–	–	–	–	–	–	4 625	7 725
Sub-Total		**51 801**	**53 255**	**66 954**	**76 707**	**95 492**	**102 026**	**102 498**	**114 783**	**118 663**	**106 376**	**116 584**	**114 022**	**118 257**
2.12	**Administration:**													
2.12.1 +	Administration (AG.)	29 126	29 366	32 824	46 356	60 632	77 239	76 828	89 839	100 423	113 065	118 057	154 267	131 995
Sub-Total		**29 126**	**29 366**	**32 824**	**46 356**	**60 632**	**77 239**	**76 828**	**89 839**	**100 423**	**113 065**	**118 057**	**154 267**	**131 995**
Grand Total		**530 269**	**577 847**	**668 766**	**727 944**	**1 085 047**	**1 363 681**	**1 437 686**	**1 668 384**	**1 532 819**	**1 586 500**	**1 833 970**	**2 087 704**	**2 283 000**

IN REPLY TO AUTHORS AND EDITORS REGARDING VOL. 19 NO. 1

Canadian Farm Economics

I have read	*and on a scale of 0 to 10, found it*		
	not useful		*very useful*
Agriculture Canada policy and expenditure patterns 1868-1983	0	5	10
Fiscal framework and agricultural expenditures in Canada	0	5	10
Federal government expenditures in the agri-food industry, 1970-71 to 1982-83	0	5	10

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Do you have any other suggestions or questions on the contents of this issue?

My comments may ( ) may not ( ) be used in a future issue of this publication. (A copy of your comments will be forwarded to the author.)

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Please return the above to:
Janice Woodcock
Editor, Canadian Farm Economics
Communications Branch
Agriculture Canada, Sir John Carling Building
OTTAWA
Canada
K1A 0C7

CONVERSION FACTORS

Metric units	Approximate conversion factors	Results in:
LINEAR		
millimetre (mm)	x 0.04	inch
centimetre (cm)	x 0.39	inch
metre (m)	x 3.28	feet
kilometre (km)	x 0.62	mile
AREA		
square centimetre (cm^2)	x 0.15	square inch
square metre (m^2)	x 1.2	square yard
square kilometre (km^2)	x 0.39	square mile
hectare (ha)	x 2.5	acres
VOLUME		
cubic centimetre (cm^3)	x 0.06	cubic inch
cubic metre (m^3)	x 35.31	cubic feet
	x 1.31	cubic yard
CAPACITY		
litre (L)	x 0.035	cubic feet
hectolitre (hL)	x 22	gallons
	x 2.5	bushels
WEIGHT		
gram (g)	x 0.04	oz avdp
kilogram (kg)	x 2.2	lb avdp
tonne (t)	x 1.1	short ton
AGRICULTURAL		
litres per hectare (L/ha)	x 0.089	gallons per acre
	x 0.357	quarts per acre
	x 0.71	pints per acre
millilitres per hectare (mL/ha)	x 0.014	fl. oz per acre
tonnes per hectare (t/ha)	x 0.45	tons per acre
kilograms per hectare (kg/ha)	x 0.89	lb per acre
grams per hectare (g/ha)	x 0.014	oz avdp per acre
plants per hectare (plants/ha)	x 0.405	plants per acre

Canada

Canadian Farm economics

Lacking vol. 19, no. 2, 1985

Agriculture
Canada

CANADIAN FARM ECONOMICS

tock economics and trade

conomics of feeder cattle and calf
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producers

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market during 1984

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Contents

The economics of feeder cattle and calf pricing in North America

G. Pugh[1]

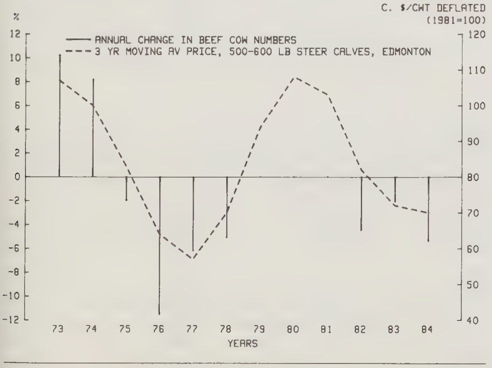
INTRODUCTION

In only five of the last 12 years have feeder cattle and calf prices in Canada and the United States been high enough to encourage expansion of beef cow herds (Figures 1 and 2). In the other 7 years market returns to most cow-calf producers were evidently below the cost of producing calves. As well as insufficient returns during the last 12 years, feeder stock prices have been volatile. Prices for feeder calves in Canada fell by half between 1973 and 1975, roughly tripled between 1977 and 1979, and then fell by about 40% between 1979 and 1984. The volatility of feeder stock prices greatly exceeded that of fed-cattle prices, and the volatility of calf prices exceeded that of heavier-weight feeders[2] (Figure 3).

This article explains the process of price determination for feeder cattle and calves in the United States and Canada. By examining the economics of feeder cattle and calf pricing, the decline of North America's beef industry during the last 10 years and the price instability that characterizes the cow-calf sector are more easily understood.

The first section contains an explanation of the price formation process and an empirical model of that process. The second section uses this model to explain observed phenomena in feeder stock markets, particularly price volatility. Particular attention is paid to the contribution of increased volatility of production costs in the feedlot sector to the instability of feeder prices. The article ends with comments on policy implications of the pricing process for feeder stock.

FIGURE 1 THE INFLUENCE OF FEEDER STOCK PRICES ON BEEF COW NUMBERS, CANADA



Although there is little new information contained in this analysis,[3] it makes price behavior in feeder markets easier to understand. Perhaps the most important observation is that feeder cattle and calf prices, and therefore cow-calf producers' incomes, are subject to more influences than just supply-demand conditions in the market for beef.

FIGURE 2 THE INFLUENCE OF FEEDER STOCK PRICES ON BEEF COW NUMBERS, UNITED STATES

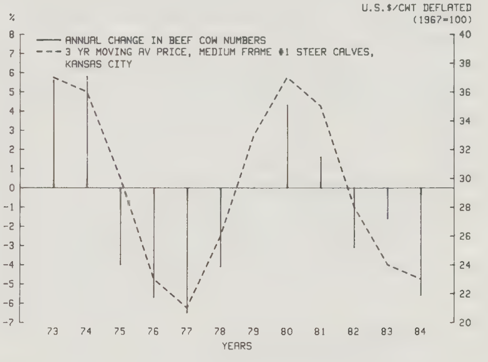
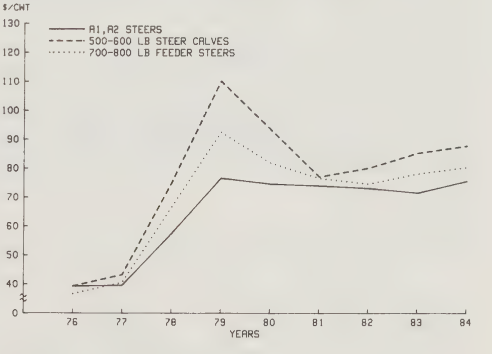


FIGURE 3 PRICE OF FED AND FEEDER STEERS, CALGARY, 1976-84



THE ECONOMICS OF FEEDER CATTLE AND CALF PRICING

In a competitive industry where producers are the sole or major user of a particular input, economic theory and observation suggest that over a sufficiently long period

neither "pure" profits nor "pure" losses exist. If anticipated revenue or the costs of other inputs change, the industry "bids away" potential profits or losses by adjusting the prices of the inputs over which it has control.

So it is with the North American feedlot industry. While the industry has no control over fed-cattle price (it being determined in a competitive market) nor over the price of most inputs (feedgrain, interest rates, labor, etc.), it is the sole user of feeder stock.

Consequently, once the industry assesses both anticipated revenue from the sale of fed cattle and the "cost-of-gain" (i.e., cost of feeding feeder cattle from purchase to selling weight), it bids away all anticipated profits or losses by adjusting the price of feeder cattle and calves.

If π is used to represent profit or loss, the above described situation can be represented as:

Equation 1

$$\pi = W \bullet P^* - B \bullet FP - (W\text{-}B)Cg$$

where:

W = finished weight of fed cattle.
P* = feedlot industry's average expectation of the price of fed steers or heifers at some point in the future.
B = purchase weight of feeder cattle or calves.
Cg = feedlot industry's cost-of-gain per hundredweight (cwt) (i.e., marginal cost of feeding), excluding the cost of feeders.
FP = price of feeder cattle or calves.

Given that the feedlot industry is both competitive and the sole user of feeder cattle, feeder prices are bid up or down as P* and Cg change such that on average $\pi = 0$. In other words:

$$0 = W \bullet P^* - B \bullet FP - (W\text{-}B)Cg$$

The price of any weight class of feeder animal, therefore, can be expressed in terms of both the expected value of fed cattle and the feedlot industry's average cost of finishing cattle:

Equation 2

$$FP = \frac{W \bullet P^* - (W\text{-}B)Cg}{B}$$

In other words, the value of any weight class of feeder animal equals the difference between the feedlot industry's assessment of the future value of fed cattle and the average cost of feeding steers or heifers to finished weight. In effect, the feedlot industry bids all anticipated revenue over and above the cost of finishing into the value of feeder cattle. This difference, divided by the purchase weight of the feeder animal, gives its price.

While equation 2 adequately explains how feeder cattle prices are determined, the process would be easier to conceptualize if feeder stock prices were expressed in terms of expected revenue per cwt (i.e., fed-cattle prices) and the per cwt cost of finishing cattle. This can be done by modifying equation 2:

Equation 3

$$FP = P^* + \frac{W\text{-}B}{B}(P^* - Cg)$$

Equation 3 says that the per cwt value of a feeder animal is equal to its anticipated per cwt value as a finished animal plus (or minus) the anticipated net revenue gain (or loss) during the feeding period per cwt of purchase weight. Thus, for example, if the feedlot industry anticipates that the fed-steer price will be \$80/cwt, and if the industry's cost-of-gain is on average \$65/cwt, then a 650 lb feeder steer would be priced at:

$$\$80 + \frac{1100 - 650}{650}(\$80 - \$65) = \$90.38/\text{cwt}$$

The predictive accuracy of equation 3 was tested over 10 years using data for cost-of-gain and fed-cattle prices in both western Canada and the mid-western United States. The results are reported in Tables 1 and 2, respectively.

TABLE 1 ESTIMATED AND ACTUAL PRICES FOR 700-800 LB FEEDER STEERS, CALGARY, ANNUAL, 1976-1984 ($/CWT)

	Estimated	Actual	Error
1976	37.15	36.62	+0.53
1977	39.13	40.54	−1.41
1978	67.00	66.53	+0.47
1979	91.95	92.46	−0.51
1980	82.00	82.01	−0.01
1981	76.06	76.58	−0.52
1982	77.94	74.64	+3.30
1983	79.31	78.16	+1.15
1984	81.34	80.38	+0.96

Sources: Agriculture Canada, *Livestock Market Review*
Agriculture Canada, Agricultural Stabilization Program data

TABLE 2 ESTIMATED AND ACTUAL PRICES FOR 600-700 LB FEEDER STEERS, KANSAS CITY, 1976-1984 (U.S.$/CWT)

	Estimated	Actual	Error
1976	35.42	39.40	−3.98
1977	40.24	40.18	+0.06
1978	60.18	58.74	+1.44
1979	82.63	83.08	−0.45
1980	76.42	75.23	+1.19
1981	67.44	66.24	+1.20
1982	72.51	64.82	+7.69
1983	65.23	63.71	+1.52
1984	67.05	65.28	+1.77

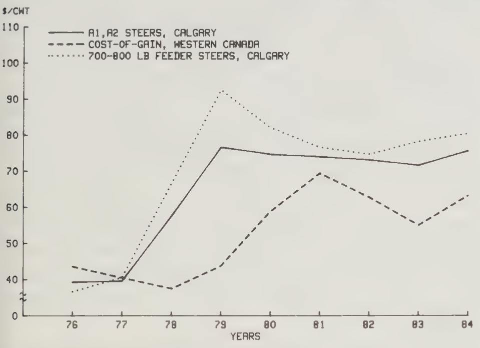
Source: USDA, *Livestock and Meat Situation*

Implications of the process of price formation

The relationship expressed by equation 3 clearly suggests why feeder cattle prices can move independently from fed-cattle prices. If P* exceeds Cg, a net gain in revenue is anticipated during the feeding period. This extra anticipated revenue is bid into feeder prices and feeder prices exceed the per cwt value of finished cattle. Conversely, if the Cg exceeds P*, a net loss is anticipated during the feeding period. This loss, per cwt of purchase weight, is bid off the per cwt value of finished cattle.

Therefore, if P* exceeds Cg, prices of feeder cattle of all weights will be greater than fed-cattle prices. If Cg exceeds P*, however, feeder prices will be less than fed-cattle prices (Figure 4).

FIGURE 4 RELATIONSHIP BETWEEN FED-CATTLE PRICES, COST-OF-GAIN AND FEEDER CATTLE PRICES IN WESTERN CANADA, 1976-84



It should also be clear why feeder prices are more volatile than fed-cattle prices and why the volatility of feeder stock prices increases the lighter the weight of feeder animals. Any change in P* implies a change in total anticipated revenue from the sale of finished cattle. Since all revenue over and above the cost of finishing is bid into the value of feeder stock, this revenue change implies a greater per cwt change in the value of feeder cattle because there are fewer pounds of feeder animal over which to distribute the revenue change. It should also be clear, therefore, that the size of the price change for feeder cattle, in response to a change in fed-cattle prices, increases as the weight of the feeder animal decreases.

Equation 3 also suggests that price of any weight class of feeder is affected more by changes in anticipated fed-cattle prices than by changes in cost-of-gain.[4] While a change in cost-of-gain applies only to the weight gained during the feeding period (affecting the anticipated net revenue loss or gain for that period), a change in expected fed-cattle prices affects the anticipated revenue loss or gain during the feeding period as well as the value of the weight which the animal has already gained.

It follows, therefore, that the magnitude of the change in price for any weight category of feeder animal, in reaction to changes in either fed-cattle prices or cost-of-gain, is relatively fixed. Table 3 lists effects of changes of fed-steer prices and of cost-of-gain on the prices of feeder steers of different weights. For example, a 10% rise in the expected fed-steer price causes prices of all feeder steer weight ranges to rise by a basic 10% plus an amount based on weight (a further 11% for calves weighing 500-600 lb), whereas a 10% rise in the average cost-of-gain tends to reduce the price of 500-600 lb steers by 11% and that of 800-900 lb steers by 4%.

Although the cost-of-gain exerts less influence on the prices of feeder cattle than do fed-cattle prices, the importance of cost-of-gain has increased markedly in the last 10 years. Increases in costs for cattle-feeding enterprises have been high. The estimated cost-of-gain for feedlots in western Canada (Table 4) increased by 85% between 1978 and 1981, fell by 21% between 1981 and 1983 and then increased again in 1984 by 15%. The net increase in cost-of-gain between 1978 and 1984 was 69% compared to a 31% increase in fed-cattle prices. As shown in Table 5 the major sources of fluctuation in cost-of-gain were feed and interest costs. The dominant role of feed costs in total cost-of-gain is also evident.

TABLE 3 EFFECTS ON PRICES OF FEEDER STEERS (BEING FED TO 1150 LB) OF CHANGES IN EXPECTED FED-CATTLE PRICES AND COST-OF-GAIN (%)[1]

10% change in	500-600 lb	600-700 lb	700-800 lb	800-900 lb	900-1000 lb	1000-1100 lb
P*	+21	+18	+15	+14	+12	+11
Cg	−11	− 8	− 5	− 4	− 2	− 1

[1] "+" indicates a change in the same direction
"−" indicates a change in the opposite direction

TABLE 4 RELATIONSHIP BETWEEN FED-CATTLE PRICES, COST-OF-GAIN,[1] AND FEEDER CATTLE PRICES IN WESTERN CANADA, 1976-1984 ($/CWT)

	Price of A1,A2 steers, Calgary	Cost-of-gain, western Canada	Price of 700-800 lb feeder steers, Calgary
1976	39.20	43.56	36.62
1977	39.54	40.42	40.54
1978	57.55	37.44	66.53
1979	76.55	43.79	92.46
1980	74.59	58.82	82.01
1981	73.93	69.39	76.38
1982	73.08	62.73	74.64
1983	71.54	55.01	78.16
1984	75.53	63.17	80.38

[1] Estimated cost per cwt associated with feeding a 750 lb steer to a finished weight of 1100 lb

Sources: Agriculture Canada, *Livestock Market Review*
Agriculture Canada, Agricultural Stabilization Program data

Unquestionably, the increased volatility of cost-of-gain has been a major influence on feeder cattle markets during the last 10 years. Calculations based on equation 3 suggest that the increase in the cost-of-gain in western Canada between 1978 and 1981 tended to depress 750 lb steer prices by about 42.5%. In other words, 750 lb steer prices would have been 42.5% higher in 1981 than they were had there been no cost inflation between 1978 and 1981. Similarly, the price of a 750 lb steer would have been 7.5% higher in 1984 than it was had there not been a 15% increase in cost-of-gain in 1984.

It is important to note that the cost-of-gain appears to have increased more rapidly than fed-cattle prices. Consequently, despite a major increase in fed-cattle prices since the mid-1970s, feeder cattle prices have been eroded.

TABLE 5 PROPORTION OF ESTIMATED COST-OF-GAIN FOR A 750 LB FEEDER STEER ACCOUNTED FOR BY VARIOUS FACTORS IN WESTERN CANADA (% OF COST-OF-GAIN)

	Feed cost	Interest cost	Other
1976	72	7	21
1977	68	7	25
1978	62	10	28
1979	54	19	27
1980	60	17	23
1981	63	16	21
1982	58	17	25
1983	54	15	31
1984	61	12	27

Source: Agriculture Canada, Agricultural Stabilization Program data

CONCLUSIONS AND OBSERVATIONS

The analysis in this article is intended to clarify the economics of feeder cattle pricing within the North American industry. Feeder prices tend toward expected fed-cattle prices plus a percentage of the anticipated margin (which may be negative) between fed-cattle prices and the industry's average cost-of-gain during the feeding period. Changes in either cost-of-gain or expected fed-cattle prices will change feeder prices, but the effect of changes in expectations of fed-cattle prices is greater.

The analysis indicates why feeder cattle prices are, in general, more unstable than fed-cattle prices. In the first instance, the mechanism of feeder cattle price formation (i.e., feeder prices being based on the residual of anticipated revenue and anticipated costs in the feedlot industry) inherently gives rise to greater price variation than occurs for fed cattle.

In addition, feeder cattle prices are affected not only by anticipated supply-demand conditions in the fed-cattle market, but also by changes in the numerous components of cost-of-gain. The major components, feed and interest costs (which account for about three-quarters of total cost-of-gain), have become very unstable themselves, adding to the factors causing greater price variability for feeder cattle.

Opinions differ about the future long-term direction of feedgrain prices and interest rates. There seems to be little disagreement, however, that the volatility of these cost factors can be expected to continue for the foreseeable future. Increased instability in international monetary markets and feedgrain policies of major grain-exporting countries are just two of the factors that will ensure continued instability.

If the widespread abandonment of the cow-calf industry is to be halted, the profitability of producing feeder stock will have to increase substantially. During the next year or two, feeder prices are expected to improve since beef supplies will decrease (based on the past 3-4 years of herd liquidation) and major costs of production have decreased. However, beyond this period there is no guarantee that feeder prices will not be further eroded by major increases in cost-of-gain. A major decrease in the value of the U.S. dollar or severe crop failure in a major producing country would likely raise feedgrain prices and would affect the value of fed cattle. Similarly, higher interest rates would also increase feeder costs.

Given these uncertainties with respect to cow-calf producers' incomes, it becomes apparent that production efficiency and cost saving within the cow-calf industry should be more actively promoted. Greater use of tested bulls, performance testing in commercial herds, and preconditioning of calves before sale are but three areas that should be considered.

As a final point, there is an important implication of the economics of feeder cattle pricing in relation to stabilization policy. It is sometimes argued that stabilization of returns to cow-calf producers can be achieved simply by stabilizing fed-cattle prices. The essence of this argument is that the effects of stabilized fed-cattle prices will trickle down to the cow-calf sector by way of adjustments in feeder cattle prices.

The economics of feeder cattle pricing, however, suggest that the impact on feeder stock prices of payments made on fed cattle could be substantially modified by changes in the cost-of-gain. At one extreme, a payment made at the same time as a substantial rise in cost-of-gain would mean that the effect of the stabilization payment would, in whole or in part, be cancelled out. At the other extreme, a payment made at the same time as a sharp decrease in cost-of-gain would amplify the rise in feeder stock prices. Moreover, rising cost-of-gain could cause feeder stock prices to decrease even while fed-cattle prices remain unchanged (as occurred between 1979 and 1981; see Figures 3 and 4). In this situation no payments to the fed-cattle industry would be triggered and the cow-calf industry would not be "stabilized".

In a competitive market, the feedlot industry adjusts to variations in revenue or cost-of-gain simply by bidding more or less for feeder stock. In a sense, therefore, the existence of the feeder stock market is a built-in stabilizer for the feedlot industry.

At the same time, it is clear that the cow-calf sector is subject to considerable price and income instability. In addition, cow-calf producers do not have any means to "pass on" cost or price changes.

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[1] Gordon Pugh is an economist with the Commodity Markets Analysis Division, Agriculture Canada.

[2] Between 1976 and 1984, for example, the price of 500-600 lb steer in Calgary exhibited an average variation from its trend value of about $19/cwt, 800 lb feeder steer averaged $11.22/cwt and A1,A2 steer averaged $10.40/cwt.

[3] It is the author's opinion that many previous analyses do not adequately analyze the economics of feeder cattle markets and the implications of market relationships. See for example Beare, O'Connor and Brokken, Short-term Forecasts of Feeder Cattle Prices, Applied Commodity Price Analysis and Forecasting, Proceedings of Conference at Iowa State University, October, 1980 and Buccola, Steven, An Approach to the Analysis of Feeder Cattle Price Differentials, *AJAE*, August, 1980. As a matter of academic interest, this paper will suggest that feeder cattle and calf prices are an implicit, non-stochastic function of fed-cattle prices and cost-of-gain. Other analyses generally emphasize an explicit, stochastic relationship.

[4] Such that

$$\frac{\triangle FP}{\triangle Cg} = \frac{-(W - B)}{B}$$

whereas $$\frac{\triangle FP}{\triangle P^*} = 1 + \frac{(W - B)}{B}$$

Canadian stabilization initiatives and their effects on the welfare of American pork producers

B. Gilmour and M. Cluff[1]

INTRODUCTION

The Canadian hog industry has grown rapidly during the last decade. Currently, large quantities of pork and live hogs are exported, primarily to the United States. This has caused concern among U.S. hog producers who contend that Canadian exports are generated by federal and provincial stabilization programs that constitute export subsidies for hog and pork products. In the fall of 1984, the American National Pork Producers Council presented a petition to the United States International Trade Commission (ITC) for the imposition of countervailing duties on Canadian pork exports to the United States. As a result of the subsequent investigation, provisional countervail duties were placed on live hogs and pork in April 1985, and finally in July, a duty was retained only on live hogs. The purpose of this article is to examine Canadian stabilization initiatives and their effects on the welfare of American producers and to identify some of the problems and questions that must be addressed if a true assessment of comparative advantage can be made. This is fundamental to the determination of "injury" actually suffered by American producers.

On September 21, 1984, Professor G. Grimes (University of Missouri) made a presentation to the ITC in which he tried to estimate the full impact of Canadian exports on the American market. However, he did not try to demonstrate the effects of Canadian stabilization initiatives and this remains an essential issue to be addressed. For several years, trade between the U.S. and Canada has been unfettered, with the exception of certain health regulations and minimal tariffs, and significant quantities of pork have crossed the border, in both directions. Canadian stabilization programs, and other forms of intervention, have not been established with a view to influencing trade patterns between the U.S. and Canada. Canada has long been seen as a "price taker" on the North American market, implying that such programs have a minimal impact on this market. It is, therefore, important and opportune to investigate whether this is really the case.

Initially, this article provides a simple, but representative, portrayal of the North American pork industry. It discusses an upper-limit estimate of the effects of Canadian stabilization initiatives on the North American pork industry and assumptions underlying this upper limit. An alternative estimate is provided for the consequences of Canadian stabilization initiatives, given assumptions that reflect the current situation and the manner in which producers formulate their decisions. Finally, other factors are reviewed that have been either ignored or discussed only casually to date but have contributed significantly to the present situation. From the analysis presented in this article, it appears that Canadian stabilization programs have a minimal impact on the U.S. market. This finding is consistent with Canada's general approach to stabilization in that it recognizes the small role the Canadian industry plays in the North American agricultural market.

PRELIMINARY DISCUSSION

The issue at hand is not to determine whether Canada/U.S. hog and pork trade should continue; rather, it is whether the present trade balance is "unfair" as a result of government intervention and, consequently, whether any case for compensatory action exists. Therefore, the relevant question for an inquiry is, "What would happen to the North American live hog and pork market if all current government assistance and stabilization programs (American and Canadian) were discontinued?" A thorough inquiry should also ascertain the quantity of Canadian exports generated by relatively higher support provided by governments in Canada (although this "higher" support remains to be documented). This article does not provide a conspectus of all factors that impinge on pork production levels and the balance of trade but it attempts to make the issues that should be addressed more cogitable. To accomplish this, an assessment of the possible effects that Canada's stabilization programs have on production levels, prices and trade is attempted. Finally, some of the broader issues which are relevant to stabilization, trade and their effects on American producers are discussed.

It is not easy to discuss or assess the precise impact of Canadian stabilization initiatives. The most difficult issues concern the nature of the programs themselves since they are not designed to stimulate production at the margin. For example, the pork stabilization program under the Agricultural Stabilization Act (ASA) has a selected "support" level considerably below projected long-term price levels or measured costs-of-production. With such programs, marginal costs are still greater than marginal revenues (even with the support payments) for the years in which support payments are made; significant supply response is not expected since support levels are not indicative of long-term price or margin trends and these are the factors upon which pork producers base their production decisions. The supply response from such stabilization initiatives can be attributed not to the subsidy component of the program, but largely to the fact that the lower end of the price or margin distribution has been truncated, resulting in substantially lower risk. It is an interesting question then whether this type of supply response can be considered for compensatory action since it is a consequence of an effective stabilization program, rather than of "unfair" government subsidies. In other

words, such supply response is due to the fact that the underwriting (ASA) scheme reduces the variance of the price distribution and not to the fact that such a scheme raises the mean of the price distribution. Having said that, stabilization payments made during 1980-83 have amounted to about 4.5% of the average price to producers and to deny that some supply response took place as a result of this price enhancement would be unrealistic (Table 1).

It is not relevant here to provide a complete description of the North American pork industry. However, it is important to emphasize that, in the main, the industry is characterized by a number of spatial markets which are interrelated in a free-trade fashion and price relationships between markets are tightly linked. The Canadian market is simply one of these and prices in this market follow price movements in American markets very closely. Canadian producers are essentially "price takers" in this setting. In the absence of government support, trade patterns should, according to classical trade theory, reflect comparative advantages by region and differential demand characteristics. In this model, differential governmental support may affect trade patterns since they affect supply and demand conditions in each market. This simplistic model excludes any account exchange differences or transportation costs. It is important to note that a shift in the supply relation in one market will result in a price change in its own market and, through the process of arbitrage, all other markets.

THE MODEL

We characterize the North American pork sector with six equations:

$Dc = a_o \cdot Pc^{a1}$	(1) Canadian demand
$Sc = b_o \cdot Pc^{b1} (1 + \alpha)^{b1}$	(2) Canadian supply
$Du = c_o \cdot Pu^{c1}$	(3) American demand
$Su = d_o \cdot Pu^{d1}$	(4) American supply
$Dc + Du = Sc + Su - K$	(5) Trade equation
$Pc = T \cdot Pu$	(6) Price transmission mechanism

where coefficients are:

a_o, a_1, b_o, b_1, c_o, c_1, d_o, d_1

where endogenous variables are:

Dc (Canadian demand — mil. cwt dressed weight)
Sc (Canadian supply — mil. cwt dressed weight)
Pc (Canadian price — C. $/cwt dressed weight)
Du (American demand — mil. cwt dressed weight)
Su (American supply — mil. cwt dressed weight)
Pu (American price — U.S.$/cwt dressed weight)

where exogenous variables are:

α (percentage subsidy through stabilization payments)
K (net trade flow to third countries)
T (price transmission mechanism, reflecting transportation and handling costs, exchange rate, etc.)

TABLE 1 NET ANNUAL HOG STABILIZATION PAYMENTS ($ MILLION)

	1980	1981	1982	1983	4-year average
Provincial programs[1]					
British Columbia	3.89	5.08	–0.57	1.91	2.58
Alberta	12.09	13.09	–1.52	3.31	6.61
Saskatchewan	3.28	5.28	–0.57	2.76	2.69
Manitoba	–	6.00	–2.21	5.61	2.35
Ontario	6.71	6.52	5.09	–3.10	3.81
Quebec	8.23	15.92	–3.39	35.00	13.94
New Brunswick	0.56	0.69	0.29	0.92	0.62
Nova Scotia	1.37	1.25	0.41	1.70	1.18
Prince Edward Island	1.81	1.43	.04	1.73	1.25
Newfoundland	–	–	–	–	
Federal	41.28	107.28	0.46	–	37.26
Total	79.22	162.54	–1.97	49.84	72.29

[1]These figures are net of producer contributions.

Sources: Regional Development Branch, Agriculture Canada
Régie des Assurances Agricoles du Québec, fiscal year basis, except 1980 which includes first three months of 1981. Quebec data computed from payments less one-third of levies and contributions. 1983 is estimated data.
Federal data from Agricultural Stabilization Board annual reports, fiscal year basis.

Note: All data are on cash received basis. Some data could not be changed to calendar year basis from a fiscal year basis.

Scenario one: welfare impacts on American pork producers — an upper limit

Our initial assumptions are:

1. Canadian stabilization payments amount to 5% of prices received, on average ($\alpha = 0.05$). This reflects the level of payments for the 4 year period 1980-83 (Table 1). However, this period is atypical of the history of stabilization assistance to the Canadian pork industry. When one considers that agents make their decisions to produce based on their expectations of long-term price and margin trends, it is apparent that this figure should reflect the historical pattern of stabilization payments. For the period 1960-84, the average payment does not exceed 1% of the product price. To make our analysis more relevant, it is later assumed that $\alpha = 0.02$.
2. It is assumed that the parameter (b_1) on the mark-up factor $(1+\alpha)$ is the same as that for the price in the Canadian supply response equation. This means that the stabilization payment is treated as a direct price subsidy and, hence, will have exactly the same impact as a comparable price increase. As indicated in our discussion earlier, this has not been determined; analysis of this kind will merely establish an upper limit to the extent of "injury" actually caused by Canadian pork stabilization initiatives. Martin and Urban (p. 11) have found some evidence that the elasticity[2] of supply response to a support price may only be one-half of the direct price response. This assumption is discussed later in this article.
3. The Canadian and American supply (of market hogs) elasticities are 0.4 in the long-run (Chin and Spearin).
4. The American and Canadian demand (for market hogs) elasticities are −0.85. This figure was selected on the basis of a literature search and reflects an average of values reported (Table 2). It should be noted, however, that the bulk of the empirical work relates to demand for pork at the retail level. A Cobb-Douglas technology has been assumed and hopefully the assumption that the market hog demand elasticity is approximately equal to the retail demand elasticity is plausible. An assessment of the sensitivity of the results under different ranges of supply and demand elasticities is provided in the Appendix. This analysis indicated that the general inferences made in this document are robust over a broad range of supply and demand elasticities.
5. Imports from Canada constituted 3.8% of the American market in 1984 (ITC). This assumption is examined later because evidence and data presented to date are not entirely consistent and this figure represents the upper end of the scale. In addition, it does not reflect the trade balance which usually predominates; i.e., the export figures for 1984 would have been considerably lower if the American dollar was not so strong and if a strike had not occurred in Canadian packing plants during 1984.
6. A live weight price of U.S.$48.00/cwt (Grimes, p. 2) has been assumed. This converts to U.S.$67.61/cwt or C. $90.15/cwt in carcass weight equivalents, assuming a 71% yield and 0.75 currency exchange rate.
7. Canadian production was 18.96 million cwt in carcass weight equivalents in 1984 (ITC, p. A-16). American pork consumption for 1984 is estimated to be 154.99 million cwt carcass weight. This projection was made by multiplying the 1983 consumption figure by the ratio of the 1984-83 January-September consumption figures (ITC, p. A-19). Since Canadian exports to the U.S. are supposed to be 3.8% of American consumption, it was initially assumed that American supply and Canadian demand were 149.10 million cwt and 13.07 million cwt respectively in carcass weight equivalents. Hereafter, all prices and quantity units are expressed as per hundredweight carcass weight equivalents. As indicated in (5), these figures must be examined more closely.

TABLE 2 ESTIMATED DIRECT-PRICE AND INCOME ELASTICITIES FOR PORK AT THE RETAIL LEVEL

Study	Period	Own-price elasticity	Income (expenditure) elasticity
George & King	1962-66	−0.41	0.13
Haidacher et al	1953-77	−0.73	0.47
Christensen & Manser[1]	1947-71	−1.03 to −1.59	0.91
Christensen & Manser[2]	1947-71	−0.38 to −0.76	0.05
Blackorby et al	1946-68	−0.69	1.13 to 1.20
Brandow	1955-57	−0.75	0.32
Hassan & Johnson[3]	1957-72	−0.93	0.25

[1]Direct Translog System
[2]Indirect Translog System
[3]Canadian data

Sources: Bessler (1984)
Hassan and Johnson (1984)

TABLE 3 CHARACTERIZATION OF EQUILIBRIA — SCENARIO ONE

	Dc	Sc	Pc	Du	Su	Pu	(1 + α)
Present situation	13.07	18.96	90.15	154.99	149.10	67.61	1.05
Removed stabilization	13.05	18.61	90.31	154.76	149.20	67.73	1.00
Percentage change	–0.2	–1.8	0.2	–0.2	0.1	0.2	–5.0

The results presented in Tables 3 and 4 depict the presumed present equilibrium (i.e., presuming assumptions (1) to (7) are appropriate) and the equilibrium which would result if Canadian pork stabilization initiatives were discontinued. The figures in these tables represent an upper limit to the possible effects that Canadian pork stabilization programs may have on the welfare of American pork producers. The price impact is approximately 12¢/cwt carcass weight or about 0.17% of the price. This translates to about $52.93 gross revenue or $38.41 producer surplus on a per-farm basis (Table 4).

TABLE 4 PROJECTED EFFECTS ON AMERICAN PORK PRODUCERS OF REMOVING CANADIAN PORK STABILIZATION PROGRAMS — SCENARIO ONE

	Gross revenue	Producer surplus[1]
Aggregate (U.S.$mil.)	24.67	17.90
Per farm ($)[2]	52.93	38.41
Price effect (U.S.$/cwt)[3]	0.12	

[1]Producer surplus is the difference between total receipts received by firms supplying some goods, and the total costs incurred by them in supplying those goods.
[2]Assuming there are 466 000 pork farms in the U.S. (ITC, p.15)
[3]Dressed weight

Scenario two: expectations and production decision linkages

It is conceivable that producers treat stabilization payments as unanticipated windfalls. Indeed, this is quite plausible when one considers the retroactive nature of ASA assistance since the actual payments for a particular commodity are made in the latter part of the following year. It is clear that the actual payments, when received at a late date in a lump sum, are unlikely to directly affect producers' production decisions. If the producer does treat the payment as a lump-sum gain, it has no effect on his perception of relative prices and, hence, will not alter his decisions regarding the optimal intensity of production.

Given the validity of the observations above, the main mechanism through which support payments alter producers' production decisions must be through their effects on producers' expectations. To document or prove "injury" to American pork producers as a result of Canadian stabilization initiatives, one must be able to detail explicitly and document empirically the support-payment/expectation/production-decision linkages. However, the precise manner in which producers incorporate support payments into their decision-making process cannot be determined on *a priori* grounds.

At one extreme, if the producer knows the operating rules of the stabilization program and can accurately forecast the resulting price, he will view stabilization payments as a fully-anticipated stream of future income. Under these conditions, a producer who seeks to maximize his net present value will adjust the timing of his purchases and financing as well as the production intensity of his operation to reflect anticipated prices and income. In this characterization of the industry, the producer responds to anticipated support payments in precisely the same manner that he responds to anticipated prices.

Alternatively, the producer may have little information on the likelihood of assistance. Consequently, he may have no prior expectation of ASA assistance and will not include it in his production decisions. This would be the case if producers perceive a great deal of uncertainty associated with the payment and they do not wish to allow an uncertain stream of income influence their operation. Similarly, if producers are unaware of the formula by which payments are determined, they may assign a low probability to receiving support payments. Under such circumstances, producer response to stabilization payments would be nonexistent.

In the 4-year period from 1980-83, Canadian support payments averaged slightly less than 5% of prices received. However, it would not be appropriate to use the 5% figure to project the anticipated supply response to stabilization initiatives. As indicated in the preceding discussion, producers generally make their production decisions based on their expectations regarding the industry's long-term profitability. However, these expectations are likely to reflect longer-term levels of support payments. The last 4 years are atypical of the history of stabilization assistance to the Canadian pork industry. Considering that agents make their decisions to produce based on their expectations of the long-term profitability of an industry, a figure of 1 to 2% may more accurately portray present events and expectations and consequently, supply response to support payments in the Canadian pork industry.

In the discussion above, some reservations about whether the parameters in scenario one are representative were indicated. Specifically, it is important to investigate the sensitivity of the results to alternative, and perhaps more likely, values of α that represent the way in which producers regard stabilization payments. This will yield results which are more likely to reflect the manner in which producers form their expectations and, consequently, their production decisions. The results are presented in Tables 5 and 6. In this scenario, the price impact of about 5¢/cwt carcass weight is considerably smaller than that in scenario one. This translates to about $21.80 gross revenue and $16.01 producer surplus on a per farm basis (Table 6).

One should be cautioned, however, that all of the results documented in this article are based on conjecture. In a thorough treatment and assessment of the effects of such government programs, these support-payment/expectation/production-decision linkages must be modelled explicity and tested empirically to ensure that the theory adequately encompasses and predicts events in the real world. To date, no such empirical studies have been conducted.

Scenario three: supply response to support price levels

Thus far, it has been assumed that the transmission mechanism for $(1+\alpha)$ is the same as that for price in the Canadian supply response equation. However, most analysts would agree that the type of stabilization payment in question does not have a direct price effect and that producers are much less responsive to support level increases than price increases, if they respond at all. Martin and Urban found that the elasticity of producers' responses to higher support price levels were approximately one-half that of the direct price response. While their results are not necessarily representative of the present area of examination, they are certainly superior to the assumption of identical parameters for the price and stabilization payments. In an effort to encompass this type of response mechanism, the Canadian supply equation was rewritten as follows:

$$Sc = b_o \, Pc^{b1} \, (1 + \alpha)^{0.5b1}$$

The results of simulation for this specification are presented in Tables 7 to 10. Tables 7 and 8 illustrate the effects of solely adjusting this response mechanism. Tables 9 and 10 illustrate the combined effects of the arguments in scenarios two and three.

Given that scenario three (b) is the most representative thus far, it is worthy of some discussion. American producers would gain $0.02/cwt or approximately 0.03% of the prevailing price from the removal of Canadian stabilization initiatives, amounting to about $6.42 of producer surplus on a per-farm basis. These figures can be contrasted with those of Grimes, which were estimates for the potential effects of suspending trade. Grimes' figure for a change in prices is about $2.68/cwt, or about 130 times our figure. This illustrates the trivial effect that Canadian pork stabilization programs have on our trade position with the United States and on the North American market. Addressing the issue of the impact of stabilization on trade and prices as opposed to the issue of the impact of trade on prices are indeed two very different ventures.

TABLE 5 CHARACTERIZATION OF EQUILIBRIA — SCENARIO TWO

	Dc	Sc	Pc	Du	Su	Pu	$(1 + \alpha)$
Present situation	13.07	18.96	90.15	154.99	149.10	67.61	1.02
Removed stabilization	13.06	18.82	90.21	154.90	149.14	67.66	1.00
Percentage change	–0.1	–0.7	0.1	–0.1	0.0	0.1	–2.0

TABLE 6 PROJECTED EFFECTS ON AMERICAN PORK PRODUCERS OF REMOVING CANADIAN PORK STABILIZATION PROGRAMS — SCENARIO TWO

	Gross revenue	Producer surplus[1]
Aggregate (U.S.$mil.)	10.16	7.46
Per farm ($)[2]	21.80	16.01
Price effect (U.S.$/cwt)[3]	0.05	

[1]Producer surplus is the difference between total receipts received by firms supplying some goods, and the total costs incurred by them in supplying those goods.
[2]Assuming there are 466 000 pork farms in the U.S. (ITC, p.15)
[3]Dressed weight

TABLE 7 CHARACTERIZATION OF EQUILIBRIA — SCENARIO THREE-A

	Dc	Sc	Pc	Du	Su	Pu	$(1 + \alpha)$
Present situation	13.07	18.96	90.15	154.99	149.10	67.61	1.05
Removed stabilization	13.06	18.78	90.23	154.87	149.15	67.67	1.00
Percentage change	–0.1	–0.9	0.1	–0.1	0.0	0.1	–4.8

TABLE 8 PROJECTED EFFECTS ON AMERICAN PORK PRODUCERS OF REMOVING CANADIAN PORK STABILIZATION PROGRAMS — SCENARIO THREE-A

	Gross revenue	Producer surplus[1]
Aggregate (U.S.$mil.)	12.34	8.95
Per farm ($)[2]	26.48	19.21
Price effect (U.S.$/cwt)[3]	0.06	

[1]Producer surplus is the difference between total receipts received by firms supplying some goods, and the total costs incurred by them in supplying those goods.
[2]Assuming there are 466 000 pork farms in the U.S. (ITC, p.15)
[3]Dressed weight

averse firm is better off by decreasing its production than by increasing its production when conditions of uncertainty prevail; risk is not necessarily reduced when production is reduced.

Turnovsky demonstrated that there are three key features of an industry to consider when making conjectures regarding the production response to risk and, as corollaries, certain types of stabilization schemes. Specifically, they are: the precise nature of the firms' underlying cost curves; the manner in which firms formulate their expectations; and, the firms' attitude toward risk. Obviously, *ex post* adjustment depends upon the initially chosen plans; the firm's problem becomes one of selecting its *ex ante* decisions optimally, taking into consideration its *ex post* adjustment possibilities.

TABLE 9 CHARACTERIZATION OF EQUILIBRIA — SCENARIO THREE-B

	Dc	Sc	Pc	Du	Su	Pu	$(1 + \alpha)$
Present situation	13.07	18.96	90.15	154.99	149.10	67.61	1.02
Removed stabilization	13.07	18.89	90.18	154.94	149.12	67.63	1.00
Percentage change	0.0	–0.4	0.0	0.0	0.0	0.0	–2.0

TABLE 10 PROJECTED EFFECTS ON AMERICAN PORK PRODUCERS OF REMOVING CANADIAN PORK STABILIZATION PROGRAMS — SCENARIO THREE-B

	Gross revenue	Producer surplus[1]
Aggregate (U.S.$mil.)	4.35	2.99
Per farm ($)[2]	9.33	6.42
Price effect (U.S.$/cwt)[3]	0.02	

[1]Producer surplus is the difference between total receipts received by firms supplying some goods, and the total costs incurred by them in supplying those goods
[2]Assuming there are 466 000 pork farms in the U.S. (ITC, p.15)
[3]Dressed weight

IMPLICATIONS OF EX POST PRODUCTION FLEXIBILITY

The foregoing discussion is based upon the implicit assumption that all producer decisions affecting production must be made *ex ante*. However, the pork industry is one in which there is a substantial amount of *ex post* production flexibility. That is to say, producers may revise their production plans as they receive more information on the market conditions that will prevail at the time of slaughter. This has some rather significant implications.

Turnovsky (1973) has observed that, under certain conditions, a risk averse firm with *ex post* production flexibility to newly acquired information may well produce at a higher level than a risk neutral firm when faced with uncertainty.[3,4] Consequently, efforts to stabilize the industry could result in a reduction in supply; conversely, the removal of stabilization programs may result in supply expansion. Newbery and Stiglitz (1981) have echoed these sentiments — there is nothing to say whether the risk averse firm is better off by decreasing its production than by increasing its production when conditions of uncertainty prevail; risk is not necessarily reduced when production is reduced.

Turnovsky's sequential decision approach is easily shown to be more encompassing than the traditional approach. Consider the implications of the two limiting cases of zero and infinite *ex post* flexibility. If there are zero *ex post* production possibilities, we are simply examining the conventional case of decision-making under conditions of uncertainty. However, if there is perfect flexibility, the firm can produce just as cheaply after as it can before it gains the new information on what market conditions will prevail at the time of slaughter. Clearly, this implies that the initial plans are of no consequence; the firm is obviously better off to postpone all decisions until the information on market conditions becomes available. If this characterization were appropriate for the pork industry, one could simply model production response as if there were no uncertainty. However, the point to be made here is that *ex post* production adjustment is not costless. As a result, some decisions must be made before farmers gain information on future market conditions.

Suppose that the marginal cost of making *ex post* production adjustments is greater than zero. This means that the marginal cost of making adjustments of a given magnitude increases with the size of the original plans. The risk faced by the firm is contracted as soon as it commits itself to a production plan before the information on eventual market conditions becomes known and with *ex post* adjustment possibilities it is by no means clear that a reduction in planned activity will lead to a reduction in risk (Turnovsky, p. 409). Hence, the firm can reduce the likelihood that it will eventually wish to increase its output beyond its original plan simply by increasing its original

plan. Of course, this increases the chances that it will wish to make an *ex post* downward adjustment. However, if the cost function is convex, the marginal cost of increasing plans by a given amount exceeds the marginal savings obtained if the plans are reduced by the same amount. Thus, a risk averse firm wishing to minimize the risks of having to make relatively costly upward adjustments will tend to increase its plans at the outset; the risk averse firm may actually plan to produce more than if it were risk neutral. This is because the amount of upward flexibility is limited by the original plans; hence, by increasing its initial decisions the firm is able to increase its overall flexibility, thereby reducing its risk. This phenomena may manifest itself by investment capital overcapacity (barns and breeding inventory) and seemingly counterintuitive coefficients on explanatory variables in feed conversion and average daily gain specifications.

In short, stabilization initiatives may result in reduced production in industries where *ex post* production flexibilities exist. This characterization seems to be appropriate for the pork industry and, therefore, it is imperative that an adequate empirical representation of the industry is constructed for consistent estimates of the effects of government stabilization initiatives to be obtained.

CONCLUDING REMARKS

It has been demonstrated that Canadian pork stabilization programs have a rather small impact on the North American pork market. Nothing is likely to change this general inference. There are, however, a few points worth mentioning that would cause one to alter one's precise estimate of the impact of Canadian stabilization programs and assessment of whether the present trade balance is "unfair".

First, some reservations have been put forward about whether "the changes in import volumes are too large to be explained merely as part of a normal cyclical pattern of imports between Canada and the United States" (ITC, p. 24). However, these changes in import volumes may not seem so out of line when one considers that the trade effects of a strong American dollar, a strike at Canadian packing plants and shifting consumer preferences must be superimposed on the normal cyclical pattern of trade.[5] Furthermore, Canada enjoyed a very large portion of Japanese imports of pork during 1982 and early 1983 while Denmark was kept out of the market by a hoof-and-mouth quarantine. This situation encouraged many producers and government officials to have high expectations that this situation would be ongoing, and thus they geared-up to supply that market. In 1984, when Denmark reentered the market, Canada's portion of the Japanese market was halved and the increased supply had to be marketed on this continent.

It is also true that Canadian production has increased for some time, while U.S. production has not. Furthermore, Canadian corn and feed grain prices have dropped dramatically relative to their American counterparts over the past 15 years and this is likely to have shifted the comparative advantage for pork production somewhat in Canada's favor. A proper comparison of cyclical patterns should first remove the effects that these trends have on the Canadian production and export series.

Second, from the beginning it has been assumed that Canadian initiatives have been the sole factors impinging on the pork industry. However, there are also policies in the United States which benefit American pork producers. To properly assess the "injury", one must be able to document that the relative levels of support are considerably different in the two countries. To date, this has not been addressed. However, it can be stated that the welfare estimates in scenario three should be revised downward (perhaps by one-half) to reflect the fact that American pork producers also have credit and support schemes available to them.

Third, in the analysis above we made some assumptions about the manner in which Canadian producers formulate their expectations and make their decisions. In addition, some assumptions were made about the precise supply response mechanism to support prices. In an exhaustive treatment and assessment of the effects of government programs, these relationships must be modelled explicitly and tested empirically to ensure that the theory adequately encompasses and predicts events in the real world.

Fourth, it has been stated that Canadian pork exports to the U.S. constitute 3.8% of the American market (ITC). However, this figure is not consistent with the data compiled and presented by the United States Department of Agriculture (ITC, p. A-16). While the correction of this inconsistency is unlikely to alter the results substantially, it should, nevertheless, be rectified to ensure that the assessment of alleged "injury" is as accurate as possible.

Finally, the analysis to date is a perfect illustration of Samuelson's (1972) point that analysis based on partial-equilibrium comparative statics can be extremely misleading. This is the most crucial point in the entire discussion. Thus far only the repercussions of removing the stabilization scheme pertaining to the pork industry have been examined. However, if the concept of comparative advantage is to be preserved, one should not make conjectures on the effects of a particular stabilization scheme or the consequences of its removal based purely on partial analysis. Rather, the effects of removing all externalities should be examined. In other words, the relevant question is not, "What would happen to Canadian pork production and exports in the absence of Canadian pork stabilization and industry assistance?", but rather, "What would happen to Canadian pork production and exports in the absence of all agricultural stabilization, and other government initiatives (American and Canadian)?". This is the pertinent question because the concept of comparative advantage is paramount to the entire "injury" discussion and comparative advantage is only preserved in the absence of all external factors. This approach must be advocated in preference to purely partial analysis because

of the degree of substitution between agricultural production alternatives. It can be stated without qualification that, if all agricultural stabilization initiatives in Canada and the U.S. were suspended, pork production and exports would probably not differ significantly from their present levels. Indeed, it is likely that Canadian pork production and exports would be above their present levels. Consequently, it is quite plausible that stabilization and other government initiatives (both American and Canadian) in all agricultural sectors actually benefit American pork producers. Certainly this conjecture cannot be dismissed without exploration.

From the analysis detailed here it is obvious that Canadian stabilization initiatives have, at the worst, an extremely small negative impact on American pork producers and may even be of benefit to them. It is also apparent that much empirical work is required before any accurate assessment of this impact can be made. The emphasis of this empirical work must be on the explicit documentation of the linkages between government assistance and intervention (American and Canadian) and altered producer perceptions which ultimately impinge on their production decisions. Such analysis is imperative if reasonable estimates of trade and production effects are to be obtained.

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[2] An elasticity is the percentage change in one variable caused by a percentage change in another. In this case, a demand price elasticity is the percentage change in demand due to a percentage change in price.

[3] There are a number of other situation where a risk averse firm is likely to produce more than a risk neutral firm. In the interests of brevity and simplicity, however, these are not reviewed here.

[4] In the pork industry, the producer has ample *ex post* flexibility; his initial decision to produce is made a considerable period before he actually sells the product. In such an industry, where the producer makes his decisions in a sequential manner, the producer will formulate his decisions based on the market condition expectations, and on the degree of *ex post* flexibility his decisions afford him.

[5] It seems that American consumer preferences are shifting toward the leaner Canadian product.

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APPENDIX

In this appendix, we use the model presented in the main text to examine the impact that different elasticity assumptions have on the assessment of injury to the American pork producers. The projected price effect from the removal of Canadian stabilization programs ranged from 10-19¢/cwt for the high and low elasticity responses respectively (Tables A.1 to A.6). This translates to between $50.88 and $84.00 gross revenue and between $32.00 and $60.79 producers surplus on a per-farm basis. These estimates, however, are only equivalent to the estimates presented in scenario one in the main text and a full assessment must incorporate the arguments presented later in the text. For example, we conjecture that the range of values equivalent to scenario three (b) would be about 2.5¢ to 5¢/cwt dressed, $12.01 to $19.84 gross revenue per farm and $8.00 to $15.20 producer surplus per farm for the spectrum of elasticities examined in this appendix. None of these observations alter our general assessment that the effects of Canadian stabilization programs on the North American pork market are minimal.

TABLE A.1 EQUILIBRIA WITH LOW MARKET HOG ELASTICITIES[1] — SCENARIO ONE

	Dc	Sc	Pc	Du	Su	Pu	$(1 + \alpha)$
Present situation	13.07	18.96	90.15	154.99	149.10	67.61	1.05
Removed stabilization	13.06	18.61	90.40	154.82	149.26	67.80	1.00
Percentage change	–0.1	–1.8	0.3	–0.1	0.1	0.3	–4.8

[1]Demand elasticity = –0.40, supply elasticity = 0.40

TABLE A.2 PROJECTED EFFECTS ON AMERICAN PRODUCERS OF THE REMOVAL OF CANADIAN PORK STABILIZATION PROGRAMS — SCENARIO ONE, LOW ELASTICITIES

	Gross revenue	Producer surplus[1]
Aggregate (U.S.$mil.)	39.18	28.34
Per farm ($)[2]	84.08	60.79
Price effect (U.S.$/cwt)[3]	0.19	

[1]Producer surplus is the difference between total receipts received by firms supplying some goods, and the total costs incurred by them in supplying those goods.
[2]Assuming there are 466 000 pork farms in the U.S. (ITC, p. 15)
[3]Dressed weight

TABLE A.3 EQUILIBRIA WITH MODERATE MARKET HOG ELASTICITIES[1] — SCENARIO ONE

	Dc	Sc	Pc	Du	Su	Pu	$(1 + \alpha)$
Present situation	13.07	18.96	90.15	154.99	149.10	67.61	1.05
Removed stabilization	13.05	18.44	90.37	154.71	149.32	67.77	1.00
Percentage change	–0.2	–2.7	0.2	–0.2	0.1	0.2	–4.8

[1]Demand elasticity = –0.75, supply elasticity = 0.60

TABLE A.4 PROJECTED EFFECTS ON AMERICAN PORK PRODUCERS OF THE REMOVAL OF CANADIAN PORK STABILIZATION PROGRAMS — SCENARIO ONE, MODERATE ELASTICITIES

	Gross revenue	Producer surplus[1]
Aggregate (U.S.$mil.)	38.77	23.87
Per farm ($)[2]	83.20	51.20
Price effect (U.S.$/cwt)[3]	0.16	

[1]Producer surplus is the difference between total receipts received by firms supplying some goods, and the total costs incurred by them in supplying those goods.
[2]Assuming there are 466 000 pork farms in the U.S. (ITC, p. 15)
[3]Dressed weight

TABLE A.5 EQUILIBRIA WITH HIGH MARKET HOG ELASTICITIES[1] — SCENARIO ONE

	Dc	Sc	Pc	Du	Su	Pu	$(1 + \alpha)$
Present situation	13.07	18.96	90.15	154.99	149.10	67.61	1.05
Removed stabilization	13.04	18.43	90.28	154.62	149.23	67.71	1.00
Percentage change	–0.2	–2.8	0.1	–0.2	0.1	0.1	–4.8

[1]Demand elasticity = –1.60, supply elasticity = 0.60

TABLE A.6 PROJECTED EFFECTS ON AMERICAN PORK PRODUCERS OF THE REMOVAL OF CANADIAN PORK STABILIZATION PROGRAMS — SCENARIO ONE, HIGH ELASTICITIES

	Gross revenue	Producer surplus[1]
Aggregate (U.S.$mil.)	23.71	14.91
Per farm ($)[2]	50.88	32.00
Price effect (U.S.$/cwt)[3]	0.10	

[1]Producer surplus is the difference between total receipts received by firms supplying some goods, and the total costs incurred by them in supplying those goods.
[2]Assuming there are 466 000 pork farms in the U.S. (ITC, p. 15)
[3]Dressed weight

Developments in the Canadian beef and cattle market during 1984

D. McClatchy and M. Cluff[1]

INTRODUCTION

During 1984, many factors influenced the Canadian beef and cattle market. Most notably, trade flows into and out of Canada drew attention to the extent to which the Canadian sector is integrated with the international market. The large influx of beef from the European Economic Community (EEC) and the resulting adjustments in the Canadian market were given a great deal of publicity.

The purpose of this article is to examine the developments in the Canadian market in 1984, with particular reference to the supply-utilization adjustments caused by changes in trade patterns with the EEC. The article does not purport to analyze the impact of imports from the EEC on producers' incomes, but some price developments are described summarily.

The Canadian market

The Canadian beef and cattle market is complex. Three major characteristics of the market need to be recognized before developments within the market can be understood.

First, the Canadian market functions as an integral part of the much larger North American market. With only minimal impediments to trade between the United States and Canada, beef and live cattle are both imported and exported.

The second and very important characteristic is the distinction made between "high" and "low" quality beef. In the North American market, this distinction is more significant than elsewhere in the world. This classification does not refer to quality *per se*, but to the type and characteristics of beef. High-quality beef refers to beef from grain-fed heifers and steers that is used for higher priced retail cuts. Low-quality beef is largely from cows that is sold at retail in the form of ground beef or sold for processing purposes. Estimates of Canada's trade in these categories are presented in Tables 2 to 7 and the assumptions used to make these estimates are provided in the Appendix. These estimates show that in 1984 high-quality beef accounted for about 60% of total beef production and consumption (by volume) in Canada; the basic point, however, is that Canada imports both high-quality beef (mainly from the U.S.) and low-quality beef (mainly from Australia, New Zealand and the EEC). Canada also has been a large exporter of low-quality beef and low-quality type live cattle (cows) to the United States. In short, Canada imports frozen boneless beef from offshore and exports fresh low-quality beef and low-quality live cattle for slaughter to the U.S. In 1984, imports of low-quality beef were about 26% of low-quality beef consumption.

The third major characteristic of the market is related to the first in that any change in existing impediments to trade in either beef or live cattle will affect the other form of trade. For example, if the U.S. were to apply its Meat Import Law to constrain beef imports into that country, Canada would likely export more live cattle for slaughter. Thus, the principal impact of such a move by the U.S. would be on the Canadian meat processing industry. Beef producers would also suffer somewhat lower returns associated with exporting live cattle to more distant U.S. markets. Similarly, a strike in the packing industry of either country would directly affect trade.

BEEF AND CATTLE MARKET QUANTITY (SUPPLY/DEMAND) CHANGES IN 1984

As noted above, Canada's beef and slaughter cattle trade is dominated by imports of low-quality beef from Australia and New Zealand, and now the EEC, and exports of low-quality slaughter cattle to the U.S. Imports of EEC beef rose from zero in 1980 to 6700 t (11.6% of total beef and veal imports) in 1983, and 22 800 t (29.3%) in 1984 (Table 1). The quantity of these imports was particularly high from mid-1983 to the end of 1984.

To what extent was this added supply of low-quality beef from the EEC absorbed by the Canadian market and to what extent did it displace such beef from other sources? Let us examine each of several possible avenues for displacement in turn.

Beef imports from other countries and beef exports

While imports of low-quality beef from Australia and New Zealand were below traditional levels in 1984, imports from Nicaragua were much higher than usual early in the year. Thus, total beef imports from non-EEC sources were marginally higher than in 1983. Consequently, the increase in low-quality beef imports from the EEC was exceeded by, though the main contribution to, the increase in total beef imports. No net displacement (or replacement) by EEC beef of beef from all other exporting countries occurred in 1984. Canadian exports of beef to the U.S. during 1984 were about 28% higher than during 1983 and this appears to reflect some displacement on the Canadian market.

Table 2 shows the distribution of beef imports and exports between high-quality and low-quality beef. Net Canadian imports of high-quality beef increased by nearly 10 000 t between 1983 and 1984, while net imports of low-quality beef declined by some 9000 t.

TABLE 1 CANADIAN TRADE IN BEEF, VEAL AND LIVE CATTLE[1]

	1982	1983	1984
Exports			
Beef & veal (fresh, chilled or frozen; tonnes, product weight)			
To U.S.	55 750	56 696	73 449
Total	60 668	61 052	77 748
Live cattle & calves (except purebred; '000 head)			
To U.S.	471	349	371
Total	477	350	377
Imports			
Beef & veal (fresh, chilled or frozen; tonnes, product weight)			
From U.S.	9 130	10 773	20 336
From New Zealand	22 597	24 752	16 073
From Australia	21 337	14 985	13 186
From EEC	3 513	6 719	22 772
From Nicaragua	202	746	4 399
Total	56 779	57 995	77 852
Live cattle (except dairy; '000 head)			
From U.S.	40	42	18
Total	40	42	18

[1]Including feeder cattle and calves
Source: Statistics Canada, *Trade of Canada*

TABLE 2 CANADA'S TRADE[1] IN HIGH-QUALITY AND LOW-QUALITY BEEF ('000 t)

High-quality	Imports Total	Imports From U.S.	Imports From others	Exports Total	Exports To U.S.	Exports To others	Net trade[2]
1983	12.13	11.75	0.83	16.10	15.27	0.83	+3.97
1984	23.31	22.94	0.37	17.35	16.78	0.57	−5.96
% change	+92.0	+95.2	−2.4	+7.1	+9.9	−31.7	N/A

Low-quality	Imports Total	Imports From U.S.	Imports From others	Exports Total	Exports To U.S.	Exports To others	Net trade[2]
1983	78.93	9.72	69.21	66.68	59.13	7.55	−12.25
1984	92.08	32.37	59.72	88.92	80.39	8.52	−3.17
% change	16.7	+232.8	−13.7	+33.0	+36.0	+17.0	−74.2

[1]Adjusted trade volumes (bone-in basis). See Appendix for conversion factors: low-quality beef trade is taken to include categories 1101, 1103, 1309, 1519, 1703 and 1709; high-quality beef trade is a 1:1 conversion of category 1105.
[2]Exports less imports
Source: Statistics Canada, *Trade of Canada*

Canadian slaughter cattle trade with the U.S.

In 1984, exports of slaughter cattle to the U.S. exceeded 1983 levels by about 50 000 head while imports of slaughter cattle from the U.S. declined by about 50 000 head, for a net change of about 100 000 head. Thus there is evidence of a substantial displacement of Canadian beef "on the hoof" into the U.S. market.

Table 3 shows the distribution of 1983-84 changes in slaughter cattle trade between higher-quality animals (steers and heifers) and lower-quality animals (cows and bulls). Table 3 also indicates the magnitude of this trade in terms of carcass weight equivalents and Table 4 distributes this slaughter cattle trade between high-quality and low-quality beef equivalents.

It can be noted that net exports of high-quality beef in the form of slaughter cattle increased by more than 21 000 t between 1983 and 1984. Similarly, net exports of low-quality beef in the form of slaughter cattle increased by nearly 8000 t.

TABLE 3 CANADIAN CATTLE SLAUGHTER AND SLAUGHTER TRADE WITH THE U.S., NUMBERS AND CARCASS MEAT EQUIVALENT[1]

	Canadian slaughter inspected ('000 hd) (a)	Canadian live imports ('000 hd) (d)	Canadian live exports ('000 hd) (e)	Canadian farm production ('000 hd) (f)	Canadian slaughter[1] ('000 t) (g)	Canadian imports[1] ('000 t) (h)	Canadian exports[1] ('000 t) (i)
Steers & heifers							
1983	2565.79	69.73	44.64	2540.70	699.00	19.79	11.89
1984	2404.79	18.98	92.60	2478.41	651.29	5.26	25.12
% change	−6.3	−72.8	+107.4	−2.4	−6.8	−73.4	+111.2
Cows & bulls							
1983	774.90	0.39	117.27	891.80	194.63	0.10	29.45
1984	809.21	1.17	123.42	931.46	203.15	0.29	31.00
% change	+4.4	+200.0	+5.2	+4.4	+4.4	+204.8	+5.3

[1]Based on average bone-in carcass weights for each animal type for each year
Source: Agriculture Canada, Markets Information Services
Note: a + e − d = f

TABLE 4 HIGH-QUALITY AND LOW-QUALITY BEEF EQUIVALENTS (BONE-IN BASIS) OF CANADIAN SLAUGHTER CATTLE TRADE ('000 t)

	High-quality		Low-quality					
			Exports			Imports		
	Total exports	Total imports	Steer/ heifer	Cow/ bull	Total	Steer/ heifer	Cow/ bull	Total
1983	9.21	15.35	2.67	29.45	32.11	4.44	0.10	4.54
1984	19.48	4.08	5.64	31.00	36.64	1.18	0.29	1.47
% change	+111.5	−73.4	+111.4	+5.3	+14.1	−73.4	+204.8	−67.7

Source: Table 3, using a high/low quality percent output of 77.55/22.45 for steers/heifers (see Appendix). Cow/bull carcasses are assumed to be 100% low-quality.

Canadian farm production of beef as slaughter cattle

The approach to estimating the level of Canadian farm production of beef in the form of slaughter cattle involves first estimating the production of each quality of carcass beef and then adjusting this for the carcass weight equivalents of the net trade in slaughter animals. The results of these calculations are summarized in Table 5.

In 1984, total Canadian farm production of beef in the form of slaughter cattle declined by 10 000 t (carcass weight equivalent); domestic production of high-quality beef declined by 15 000 t while production of low-quality beef increased by 5000 t. Thus, it appears that the effects of increased imports of low-quality EEC beef were not dampened by a decline in Canadian farm production of low-quality beef.

Canadian consumption

Increased supplies can also cause changes in consumption patterns, in this case, increased Canadian consumption of low-quality beef. This may involve some substitution of low-quality beef for high-quality beef in the Canadian diet, and possibly some substitution of beef for other meats.

As shown in Table 6, some decreased Canadian consumption of both high-quality beef and low-quality beef is indicated. Although the relative share of low-quality beef in total beef consumption increased slightly in 1984, it cannot be concluded that the increased supplies of imported beef resulted in increased levels of Canadian consumption of that type of beef.

TABLE 5 CANADIAN HIGH-QUALITY AND LOW-QUALITY CARCASS BEEF PRODUCTION AND FARM PRODUCTION IN THE FORM OF SLAUGHTER CATTLE ('000 t)

	Steer/heifer beef[1] (a)	Cow/bull beef (b)	Total carcass beef production (c)	Net exports of slaughter cattle (carcass weight equiv.) (d)	Canadian farm production of beef (carcass weight equiv.) (e)
High-quality					
1983	542.07	—	542.07	−6.14	535.93
1984	505.08	—	505.08	15.40	520.48
% change	−6.8	—	−6.8	N/A	−2.9
Low-quality					
1983	156.92	194.63	351.55	27.56	379.12
1984	146.21	203.15	349.37	35.17	384.54
% change	−6.8	+4.4	−0.6	+27.6	+1.4

[1]Based on percentage of high-quality cuts: steer/heifer carcasses, 77.55% (see Appendix); cow/bull carcasses, 0%.
Sources: (a), (b): Table 3, column (g); (c) = (a) + (b); (d): Table 4; (e) = (c) + (d)

TABLE 6 SUPPLY AND DISPOSITION OF CANADIAN HIGH-QUALITY AND LOW-QUALITY BEEF ('000 t)

	Net imports (carcass weight equiv.) (a)	Canadian carcass beef production (b)	Increase in Canadian stocks (c)	Canadian consumption (d)
High-quality				
1983	−3.97	542.07	−0.13	538.23
1984	5.96	505.08	0.38	510.66
% change	N/A	−6.8	N/A	−5.1
Low-quality				
1983	12.25	351.55	6.34	357.47
1984	3.17	349.37	−3.45	355.98
% change	−74.2	−0.6	N/A	−0.4

Sources: (a): Table 2; (b): Table 5, column (c); (d) = (a) + (b) − (c)

Changes in the levels of Canadian beef stocks

Table 6 shows that the level of Canadian commercial stocks of high-quality beef changed very little during 1984. Low-quality stocks, however, declined by 3000 t, thus aggravating rather than dampening the effects of increased imports.

Overall adjustment

The accounting of Tables 2 to 6 represents an attempt to put all Canadian beef/cattle market/trade adjustments during 1984 in perspective.

It would appear that increased Canadian imports of low-quality beef in 1984 (13 000 t bone-in basis; Table 2), as a result of sharply higher EEC shipments more than offsetting reduced shipments from other major suppliers, were not absorbed into the Canadian market through any increase in Canadian low-quality beef consumption nor any decrease in Canadian farm production of low-quality beef or increase in Canadian stocks of such beef. Rather, the influx of low-quality beef into Canada was effectively passed on to the U.S. market via increased Canadian net exports of low-quality beef to the U.S. in the form of slaughter animals (8000 t bone-in meat equivalent; Table 5) and in the form of low-quality beef (21 000 t bone-in basis; Table 2).

In fact, higher Canadian supplies of low-quality beef in 1984 resulted not only from increased imports, but also from some run-down in Canadian stocks (3500 t bone-in basis; Table 6; representing a net change of approximately 10 000 t from 1983 when such stocks were increased by 6500 t) and a slight increase in domestic farm production of such beef (5000 t bone-in basis; Table 5).

In the case of high-quality beef, the 1984 picture was one of lower Canadian farm production (15 000 t; Table 5), higher net imports in the form of beef (10 000 t; Table 6), higher net exports in the form of slaughter cattle (20 000 t; Table 4) and lower Canadian consumption (28 000 t; Table 6).

By way of summary, a balance sheet of 1983-1984 volume changes for the two major classes of beef in the Canadian market can be constructed (all figures on a bone-in carcass weight equivalent basis, rounded to nearest thousand tonnes) as:

	High-quality	Low-quality
Canadian farm production (Table 5)	−15	+5
Plus increased imports as slaughter cattle (Table 4)	−11	−3
Plus increased imports as beef (Table 2)	+11	+13
Minus increased Canadian consumption (Table 6)	+27	+1
Minus increased Canadian stocks build-up (Table 6)	−1	+10
Minus increased exports as slaughter cattle (Table 4)	−10	−4
Minus increased exports as beef (Table 2)	−1	−22
	0	0

It is interesting to note that when the beef trade and the slaughter cattle trade are combined, Canada emerges as a clear net exporter of both high-quality and low-quality beef in 1984. Combined net exports of high-quality beef were 21 000 t (bone-in, carcass weight equivalent basis) and low-quality beef, 32 000 t (Tables 4 and 6). Put another way, 1984 Canadian farm production of high-quality beef represented 104% of Canadian domestic requirements and low-quality beef 107%. This little-appreciated fact, in light of high gross levels of beef imports, underscores Canada's current role as a trade conduit into the U.S. market.

Beef processing sector

The level of total carcass beef production (Column (c), Table 5) indicates the level of activity in the Canadian beef slaughtering/processing sector. Most of the decline in activity in 1984 compared to 1983 occurred in the slaughter/processing of high-quality beef (a decline of about 7% or 37 000 t of bone-in meat equivalents). This decline can be explained largely by the decreased Canadian farm production of steers and heifers, the increased exports of higher-quality slaughter animals and the decreased imports of higher-quality slaughter animals (Table 3). Factors other than the increased imports of low-quality beef also contributed to the decline in activity, such as exchange rate movements, relative Canada/U.S. packing plant labor costs and most particularly the Canadian meat-packing industry strike.

A relatively smaller decline (less than 1%) occurred in slaughter/processing of low-quality beef, to the extent of 2000 t of bone-in meat equivalents. Although some other industry-based factors also would have been at play here, it is noteworthy that this decline coincided with a 4% increase in domestic supplies of cows and bulls for slaughter.

In 1984 the U.S. Meat Import Law was not invoked and thus did not constrain Canadian beef exports to that country. The fact that increased supplies of low-quality beef on the Canadian market were transmitted to the U.S., partly in the form of increased net exports of slaughter cattle (8000 t carcass weight equivalent) and partly as increased net exports of low-quality beef (21 000 t carcass weight equivalent), can presumably be explained in terms of relative U.S./Canada meat-packing industry economics. In the future, however, invocation of the U.S. Meat Import Law could restrict Canadian beef exports to that country. Beyond the extent of such a restriction, beef imports into Canada could only be passed on to the U.S. market in the form of live cattle exports, with a corresponding loss in Canadian beef slaughtering/processing activity.

BEEF AND CATTLE MARKET PRICE CHANGES IN 1984

Although this article focuses principally on quantity changes in the Canadian cattle/beef sector in 1984, it is important to remember than quantity changes invariably have price repercussions and vice versa. Indices for slaughter cattle prices, wholesale beef prices and retail beef prices were all generally higher in Canada in 1984 than in 1983. However, these price rises were not as great as originally expected, given the Canadian dollar devaluation in 1984 (almost 5%), low Canadian inventories and anticipated lower North American market supplies. It is clear that substantially increased imports of EEC beef served to dampen beef and cattle price rises which would otherwise have taken place in 1984.

Differentials between Canadian high-quality and low-quality beef and cattle prices

To the extent that substantially increased supplies of low-quality beef on the eastern Canadian market were not matched by commensurate increases in high-quality beef supplies and that the two qualities of beef are not completely interchangeable in end use, we could expect increases in the market price margin between the two major grades. This in fact happened (Table 7). The margin between the price-per-unit weight of A1,A2 steer carcasses (which yield about 78% high-quality beef) and D3,D5 cow carcasses (100% low-quality) in southern Ontario showed some seasonal variation but was 15-20% higher in 1984 than for corresponding periods in 1983.

The same effect can be seen also in the slaughter cattle market (Table 8). Late summer/early fall margins between A1,A2 steers and D3,D5 cows were about 20% higher in Toronto in 1984 than in 1983.

North American inter-regional beef and cattle price differentials

The substantial increases of low-quality beef supplies, as a result of increased EEC shipments, were concentrated largely in one region (eastern Canada, mainly Montreal and Toronto). Such an influx of supplies at one point in the network which makes up the whole North American beef/cattle market could be expected, through arbitrage, to be passed on to all points in the network with a corresponding spreading of the price impacts from eastern Canada to all market points. Transportation costs, however, depending on the location of major sources of supply relative to major demand points, could possibly lead to a reduced impact at points more distant from eastern Canada.

This also appears to have occurred (Tables 7 and 8). High/low quality beef and slaughter cattle margins in the U.S. both appear to have widened, as did high/low slaughter cattle margins in Alberta, though in both cases to a lesser extent than observed in eastern Canada. Higher cow slaughter as a result of the U.S. Dairy Program (1983-84) likely also contributed to the widening in these margins.

At the same time, the margin by which Omaha cow prices exceed Toronto prices was generally higher in 1984, showing that while some transmission of the price impact occurred, eastern Canada bore more brunt of price adjustments than the U.S.

Perhaps unexpectedly, the margin by which eastern Canada slaughter cow prices exceed those in western Canada rose, if anything, in 1984. This margin was higher, in particular after June, and probably reflects higher cow slaughter in the west as a result of drought. These higher western cow marketings seem to have exacerbated the depressive impact of the increased imported supplies arriving in the east on Calgary slaughter cow prices.

TABLE 7 REPRESENTATIVE HIGH-QUALITY AND LOW-QUALITY BEEF WHOLESALE PRICES AND MARGINS, EASTERN CANADA, WESTERN CANADA AND U.S. (C. $/CWT)

	1983 Quarters				1984 Quarters			
	1	2	3	4	1	2	3	4
Steer carcass beef								
A1,A2 Toronto	137.7	145.7	133.2	134.4	147.3	148.7	146.6	147.1
A1,A2 Calgary	129.8	140.2	126.6	128.6	141.3	142.2	139.9	139.5
Choice Omaha	119.2	129.4	117.0	116.7	131.3	130.0	128.4	128.7
Ontario/Alberta margin	+7.9	+5.5	+6.6	+5.8	+6.0	+6.5	+6.7	+7.6
Ontario/Omaha margin	+18.5	+16.3	+16.2	+17.7	+16.0	+18.7	+18.2	+18.4
Alberta/Omaha margin	+10.6	+10.8	+9.6	+11.9	+10.0	+12.2	+11.5	+10.8
Cow carcass beef								
D3,D5 Toronto	97.4	110.4	105.8	90.0	98.9	107.8	106.9	93.7
Utility central U.S.	87.0	94.8	85.4	79.4	87.6	94.0	92.6	86.2
Ontario/central U.S. margin	+10.4	+15.6	+20.4	+10.6	+11.3	+13.8	+14.3	+7.5
Steer/cow carcass beef margins								
Ontario	+40.3	+35.3	+27.4	+44.4	+48.4	+40.9	+37.7	+53.4
Central U.S.	+32.2	+34.6	+31.6	+37.3	+43.7	+36.0	+35.8	+42.5

Sources: Agriculture Canada, FARM data bank
Agriculture Canada, *Livestock and Meat Trade Report*, p. 5, Wholesale Dressed Meat Prices

TABLE 8 REPRESENTATIVE AVERAGE SLAUGHTER CATTLE PRICES AND MARGINS, EASTERN CANADA, WESTERN CANADA AND U.S. (C. $/CWT)

	1983 Quarters				1984 Quarters			
	1	2	3	4	1	2	3	4
Slaughter steer prices								
A1,A2 Toronto	78.0	83.5	76.1	77.7	84.3	85.9	85.3	85.6
A1,A2 Calgary	68.6	76.5	69.2	70.7	76.0	77.2	73.2	76.1
Choice Omaha	75.5	82.5	75.1	75.1	84.9	85.3	84.5	83.7
Toronto/Omaha margin	+2.5	+1.0	+1.0	+2.6	−0.6	+0.6	+0.8	+1.9
Calgary/Omaha margin	−6.9	−6.0	−5.9	−4.4	−8.9	−8.1	−11.3	−7.6
Toronto/Calgary margin	+9.4	+7.0	+6.9	+7.0	+8.3	+8.7	+12.1	+9.5
Slaughter cow prices								
D3,D5 Toronto	47.4	51.4	48.7	41.7	47.7	51.1	51.8	45.9
D3,D5 Edmonton	39.8	46.7	42.2	35.1	41.3	45.2	41.8	36.3
Utility Omaha	49.2	52.7	48.7	43.3	49.0	54.8	53.2	49.2
Toronto/Omaha margin	−1.8	−1.3	0.0	−1.6	−1.3	−3.7	−1.4	−3.3
Edmonton/Omaha margin	−9.6	−6.0	−6.5	−8.2	−7.7	−9.6	−11.4	−12.9
Toronto/Edmonton margin	+7.6	+4.7	+6.5	+6.6	+6.4	+5.9	+10.0	+9.6
Steer/cow prices								
Toronto/Toronto margin	+30.6	+32.1	+27.4	+36.0	+36.6	+38.2	+33.5	+39.7
Calgary/Edmonton margin	+28.8	+29.8	+27.0	+35.6	+34.7	+32.0	+31.4	+39.8
Omaha/Omaha margin	+26.3	+29.8	+26.4	+31.8	+35.9	+30.5	+31.3	+34.5

Source: Agriculture Canada, FARM data bank

SUMMARY OF FINDINGS

The two previous sections describe changes in quantities and prices in the Canadian cattle/beef market in 1984. This article does not provide a definitive analysis of the causes of these changes.

The most important developments in quantities supplied, consumed and stored in 1984 appear to have been:

- Imports of high-quality beef as meat increased over 1983 levels by almost as much as imports of low-quality beef as meat.
- Imports of high-quality and low-quality beef as slaughter animals both declined, in the case of high-quality beef by approximately the same amount as the increased imports of meat.
- Exports of high-quality and low-quality beef as meat both increased over 1983 levels, significantly in the case of low-quality beef.
- Exports of high-quality and low-quality beef as slaughter animals both increased.
- Canadian farm production of high-quality beef decreased, while that of low-quality beef increased.
- Canadian consumption of high-quality beef decreased considerably while consumption of low-quality beef declined only slightly.
- Canadian stocks changes were not significant for high-quality beef, but changing stocks of low-quality beef added to market supplies in 1984 rather than contributing to demand as they had in 1983.

Condensing the above further, it can be observed that there was no increase in combined (meat and live) imports of high-quality beef, while combined imports of lower-quality beef rose by 10 000 t. More than offsetting this were increased combined exports of 12 000 t of high-quality beef and 27 000 t of low-quality beef. Overall Canadian beef production on farms and Canadian consumption both declined, but the level of domestic production exceeded the level of domestic requirements for both high-quality and low-quality beef (this was true only for low-quality beef in 1983).

The most significant quantity changes in 1984 were increased low-quality beef imports from the EEC (23 000 t), increased low-quality beef exports to the U.S. as meat (21 000 t), reduced high-quality beef imports from the U.S. as slaughter animals (11 000 t), increased high-quality beef imports from the U.S. as meat (11 000 t), increased high quality beef exports as slaughter animals to the U.S. (10 000 t), decreased Canadian farm production of high-quality beef (15 000 t) and decreased Canadian consumption of high-quality beef (28 000 t). Beef and cattle prices were generally higher in 1984, but not as much higher as decreased Canadian and U.S. cattle inventories, and marketings more commensurate with those inventories, would have generated in a more normal year.

There is evidence that price margins between high-quality and low-quality (carcass beef and slaughter cattle), between Canada and the U.S. (slaughter cattle) and between eastern Canada and western Canada (slaughter cattle) all showed a widening tendency in 1984 compared to 1983. The first two of these trends are consistent with a substantial increase in supply volumes of low-quality beef arriving on the market, initially in eastern Canada.

CONCLUSIONS

The first and major conclusion is that given Canada's relatively open import regime for beef, coupled with its close ties with the U.S. meat market and the very restrictive U.S. import quota for EEC beef, Canada effectively provides a conduit for this beef to enter the broader North American market.

A second conclusion is that to the extent that the product enters Canada in the form of meat and displaces an equivalent Canadian product into the U.S. in the form of live slaughter cattle, Canadian production and beef consumption levels may not be greatly affected, but Canadian beef slaughtering/processing activity will decline.

A third conclusion is that, since Canadian imports of beef from non-EEC sources were higher in 1984 than in either 1982 or 1983, it cannot be validly claimed that higher imports from the EEC were replacing a deficit in supplies from all other countries, in aggregate. Nor is it true that other suppliers, in aggregate, withdrew from the Canadian market in response to higher EEC shipments.

These conclusions suggest the need for Canadian beef trade policy to be closely harmonized with U.S. policy, particularly with respect to offshore trade.

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APPENDIX

Calculations of high-quality and low-quality beef

PRODUCTION DATA High-quality beef production is derived from domestic slaughter of steers and heifers, assuming that 77.55% of meat from these carcasses is high-quality beef. Low-quality beef production is derived by summing 22.45% of heifer and steer carcasses and all cow and bull slaughter.

TRADE Splitting export and import items into high-quality and low-quality beef is in many cases a difficult task, and only rough estimates are possible. The trade categories were broken down and converted to bone-in carcass weight equivalents according to the following conversion factors:

Low quality	Conversion factor
Fresh or chilled boneless (1101) (excluding U.S.)	1.4
Frozen, boneless (1103)	1.4
Cured (1309)	1.18
Sausage, fresh or cured (1519) (assumed 35% beef; 65% pork)	0.52
Corned beef (1703)	1.98
Beef and veal, canned (nes) (1709)	1.98
High-quality	**Conversion factor**
Fresh or frozen (nes) (1105)	1.0
Fresh or chilled boneless (1101) from the U.S.	1.4

Coming to grips with pesticide regulation

D. Freshwater and G. Wichenko[1]

This article summarizes a working paper prepared by D. Freshwater, University of Manitoba, and G. Wichenko, Appin Associates, in August 1985. The paper was completed under contract to Agriculture Canada and entitled 'Pesticide regulation and technological change: a discussion of the issues'.

THE RATIONALE FOR PESTICIDE REGULATION

Pesticide regulation stems from society's effort to balance two unpleasant choices. On the one hand is a general fear of insects and a dislike of pest damaged food. On the other hand is a fear of poisons and their possible contamination of food. Sanctioning the use of pesticides requires that society accept that it is applying poisons and that a direct consequence of these applications is the risk that non-target species, including humans, may be poisoned.

The rationale for pesticide regulation may be simply stated as an effort by society to reduce the risks of pesticide use to the minimum level possible for a given spectrum of pesticides and applications, while preserving some standard of food quality and public health. Implicit in this rationale is a conviction that market forces, left to themselves, will not do as good a job in reducing risk as government regulations. In making the decision on the appropriate level of use of pesticides, the government must evaluate the impact of pesticides upon a complex mix of environmental, social, economic and technological factors.

Figure 1 provides a simple schematic diagram that makes the link between the goals of society, the means we use to achieve them and the environment we live in. The three circles in Figure 1 each represent a major subsystem within the total ecosystem. The upper circle contains the set of institutional arrangements by which society is organized. The middle circle describes the set of various productive activities and transfers, which we normally consider to be the subject of economics. The lower circle consists of the natural ecosystem of the biosphere. There are flows between the upper and middle circles representing the goals and decisions of society in the form of policies, and information on performance standards of the production and distribution subsystems. Flows between the middle and lower circles represent material resource transfers into the production and distribution system and residual waste transfers back to the natural environment.

Although a simplification of the complex set of relationships between human society and the environment, Figure 1 provides a useful context in which to look at the questions of: why we regulate pesticides; how these regulations affect the various activities of society and the environment; and if the results of our regulations are what we expect and want. Clearly, the answers to these questions are not easy and this article does not come up with general responses. Rather, it examines how technological change affects society's demand for regulation, the type of regulations set and their effect on pesticide production and use.

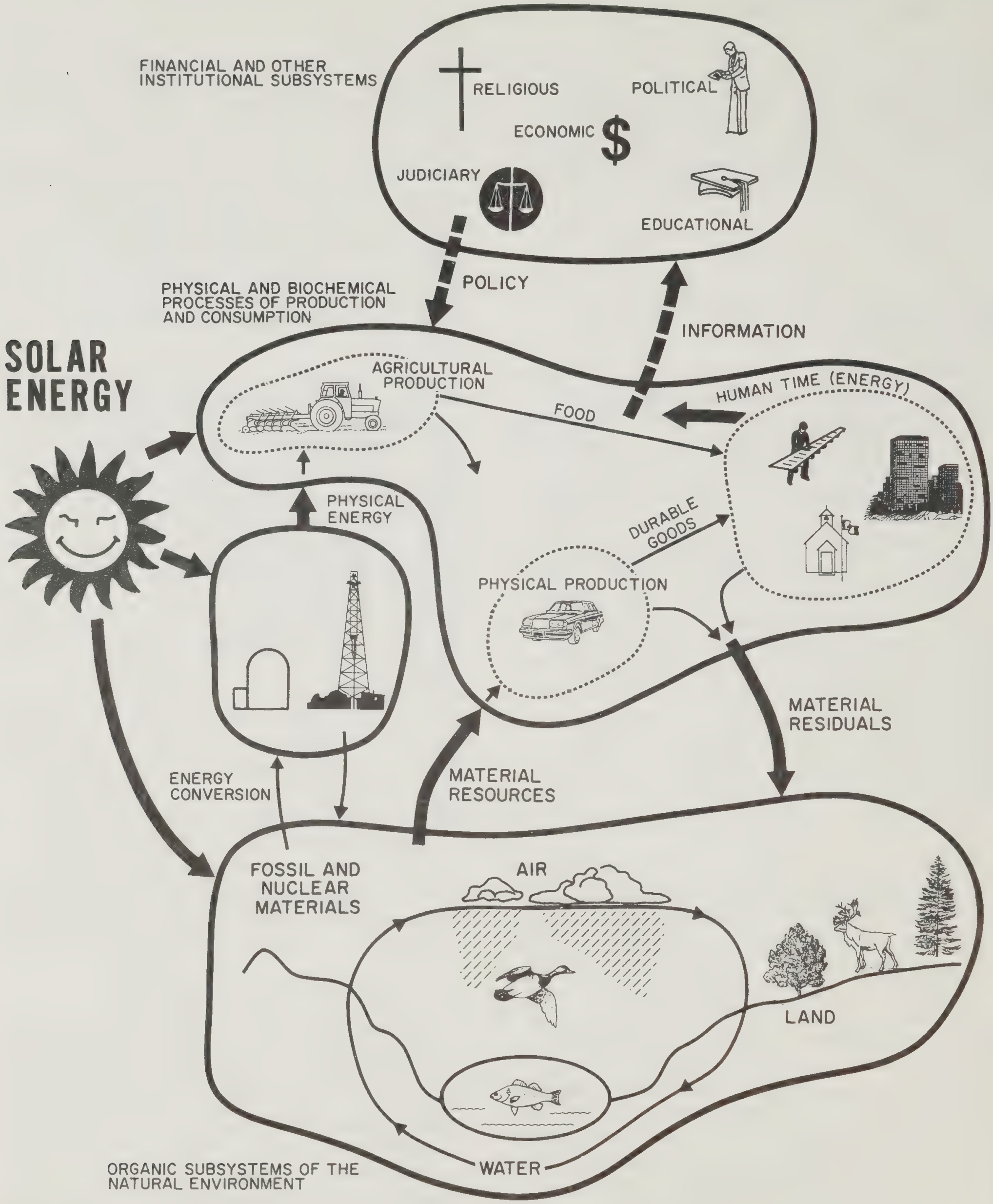
An extreme response to the dilemma would be the prohibition of the use of pesticides. However, pesticides, as a class of chemicals, are not prohibited from use for the simple reason that to do so would result in excessive costs to many members of society in terms of an increased likelihood of direct deaths from insect-spread disease and indirectly through malnutrition and starvation from the reduced availability of food supplies.[2] Therefore, society must weigh the benefits of pesticide use which accrue to the bulk of humanity against the costs to a segment of society who may experience poisoning by pesticides, induced cancers, a contaminated environment or other unpleasant effects.

In seeking to provide protection for the exposed segment of society, four areas of concern can be identified. The first is at the production site of the pesticide, where worker health regulations and manufacturing standards are employed. The second is applicator safety which involves regulations on methods and rates of use. The third area of concern is the impact on non-target species at the time of application which requires setting allowable uses, rates and methods of application. The final concern is the environmental fate of residues and by-products resulting from either the production or application of a product.

Pesticide regulation in Canada

Although various forms of pesticides have been in use over the last several centuries, government intervention in their production and marketing is a twentieth century phenomenon. In 1927, the Dominion of Canada passed the 'Act to Regulate the Sale and Inspection of Agricultural Economic Poisons'. The 1939 'Pest Control Products Act' replaced this law. The intent of both of these acts was to ensure the efficacy of products sold as pesticides. Registration of products was required and failure of a product to meet advertised claims resulted in withdrawal of registration. The focus of legislation through to the middle of this century was on efficacy, and chemicals were granted registration if they appeared to meet the manufacturers' claims.

FIGURE 1 CONCEPTUAL ELEMENTS OF THE RELATIONSHIP OF HUMAN SOCIETIES AND THE NATURAL ENVIRONMENT



Source: Koenig, H.E., T.C. Edens et al (1976), Resource Management in a Changing Environment. *Design and Management of Rural Ecosystems Project*. Michigan State University.

During the decade from 1950-60, a general recognition of the harmful effects of pesticides developed. The initial focus of concern was on non-target species effects and residues in food and feed. In 1952, Canada revised the Pest Control Products Act requiring applicants to provide evidence of the safety as well as efficacy of their product. A further and more extensive revision of the act in 1968 resulted in a major shift in focus from efficacy to safety; only registered uses of chemicals were permitted and products were classified on the basis of their use and safety as domestic, commercial or restricted. Registrants also had to provide data on uses in terms of safety and efficacy.

Throughout the 1970s legislation controlling the registration and use of pesticides was modified. Each modification resulted in more stringent data requirements from the registrant, in terms of safety to humans, animals and to the general environment. This concern with general environmental effects is the hallmark of pest control legislation in the period. By 1981, 31 federal statutes dealt with pesticides. In addition, the 10 provinces and two territories administered another 101 pesticide-related statutes.

Regulation both in direct and indirect forms permeates the pesticide market, affecting both supply and demand but has not directly affected the level of output or pricing decisions of firms nor formally limited entry. Thus, the pattern of regulatory activity differs from the standard economic model both in terms of intent and process. The regulatory influence has been directed towards providing information to consumers and protection to users and the environment from harmful effects that are associated with pesticides but not readily taken into account by an individual's decision-making process.[3]

As information about the magnitude and diversity of the undesirable consequences of pesticide use increased, so did the scope of the regulations. If we interpret the technology which is in place in a society at a point in time to include scientific knowledge as well as industrial processes, then we can say that as the technology associated with the sciences of toxicology, biology and environmental systems expanded, so did the concern with pesticides and their regulation. These concerns led to efforts to manage the development and use of pesticides through regulation.

Over the past 50 years the number of regulations in Canada dealing directly with pesticides has increased from one in 1927 to 132 in 1981. In addition, a large number of statutes, such as those governing worker safety, patent regulations and other general forms of regulation, indirectly affect the production and use of pesticides. Given this remarkable increase, the obvious question to ask is what are the effects of these regulations on technological change within the industry?

REGULATION AND TECHNOLOGICAL CHANGE

Not a great deal is known generally about the impact of regulations on technological change and even less specifically on the effects of pesticide regulations on technological change within the pesticide industry. One of the few documents on the subject was prepared by Ashford et al, entitled *Environmental Safety Regulation and Technology Change in the U.S. Chemical Industry*. Ashford notes that, "it is essential to distinguish between two separate effects of regulation on technological change — the technological changes necessary for compliance purposes and the other, ancillary changes in technology which may also result."[4] Regulations which force compliance may stimulate technological change. Regulation can also discourage innovation in a direct way such as refusal to permit unsafe products, or in an indirect way, such as the costs of environmental control. Finally, Ashford notes that, "there can be a systematic effect which will significantly affect the skill mix of chemical firms, the R&D process in them and their general business strategy for the foreseeable future. These effects will in turn have important, though still largely unpredictable, effects on the nature of the innovation process in the chemical industry".[5] Ashford's model of the regulation-technological change relationship consists of the regulatory stimulus, the responding unit or units and the technological response.

The factors that induce technological change have also been summarized by Scherer whose argument relates the structure of the market in which firms operate to their incentive to innovate.[6] Scherer identifies five main factors:

1 the size of the overall profit potential in the market;
2 the number of participants who will potentially share the profit;
3 the reaction speed of rival firms;
4 the degree to which being first conveys permanent product differentiation; and
5 the magnitude of the expected research and development costs.

Consideration of the impact of pesticide regulations on each of Scherer's five factors suggest that the net result on willingness to innovate is unclear. For example, the size of the overall profit from a new chemical is governed by the uses it is licensed for. Licensing for each use, however, involves additional costs for efficacy tests. Similarly, patent protection conveys 17 years of protection from the time the patent is filed, which encourages product development, but the process of developing and providing registration data before actual marketing of the product reduces the useful lifespan of the patent. Other positive and negative effects can be identifed with various regulations.

One of the major economic arguments against regulation is that it ultimately leads to those being regulated making use of the regulations for their own purposes. In the pesticide industry, it can be argued that the lengthy period of time and considerable investment required to register chemical compounds create effective barriers to entry, particularly for small firms. This argument suggests that, over time, licensing regulations squeeze small firms out of the industry leaving only giant multinationals. Such an argument is consistent with the observed trends in the industry.

It is not clear, however, that such a trend is harmful to innovation. One can also argue that the presence of monopoly power and a secure market provides an incentive to innovate as suggested by Scherer's points 2, 3, and 4. Thus, capture theory, while suggesting that excess profits may be earned in the short run, may lead to a greater degree of innovation over time than would occur in an industry structure which is more competitive.

THE EFFECT OF TECHNOLOGICAL CHANGE ON PESTICIDE REGULATIONS

If regulations are to be assessed, it must be in terms of their ability to perform their primary task, which is to reduce the burden of costs to society from using pesticides. Over time one can observe that as additional scientific information is made available, regulations have adapted to include that information. Thus, as better toxicological tests are developed they are included in registration procedures. Similarly, the prohibition of long-life broad-spectrum pesticides for most uses arguably resulted in an incentive to firms to develop specialized short-life pesticides, if for no other reason than the market created by the prohibition.

Technology, in a broad sense, has other effects upon pesticide regulations. Regulations primarily influence the supply of pesticides. Technological change in other sectors of agriculture is altering the demand for pesticides. To the extent that minimum or reduced tillage practices are adopted to reduce energy consumption or soil erosion, there will be a related increase in the demand for pesticides. As a result, regulations that were based on lower use levels of chemicals may become inappropriate with greater use.

It would seem to be the case that regulation can induce changes in technology and technology can induce changes in regulation. A basic question is whether these feedback effects enhance or detract from the welfare of society. The focus of the literature on technological change has been on the rate of adoption of new technology. This literature implicitly assumes that new technology is available and that it is desirable from both an individual's and society's points of view. Regulatory activity can affect both of these assumptions. By precluding the use of particular technologies because they have certain characteristics deemed undesirable, regulation can remove a technology from consideration. Thus, the Delaney clause in the U.S. Food and Drug Act prohibits the use of cancer-inducing compounds no matter how slight the risk of cancer. Similarly, regulation can prohibit the adoption of technology that may be advantageous to either an individual or society collectively, but not to both. As a result the set of choices open to individuals and society is restricted.

Regulations may also change relative prices resulting in different combinations of goods being produced and distributed than would be in a regulation-free world. Precluding the importation of pesticides by Canadian farmers for their own use appears to have raised the cost of using at least some herbicides, causing higher costs of production.[7]

Over time the pattern of innovations may also be affected, causing a different path of development for society. To the extent that new technology affects the demand and supply of regulations, creating a need for new regulations and making old regulations obsolete, one could argue that technological and regulatory change are jointly determined. A number of forces are central to the evolution of pesticide regulations, the major technological and scientific changes being: advances in the science of toxicology; concerns about the ecological impact of pesticides; issues relating to the occupational and health hazards of pesticides; advances in measurement technology (instrumental analysis); improvements in the manufacturing of pesticides; changes in agricultural production techniques; and the evolution of Integrated Pest Management (IPM).

A full discussion of the nature of those changes is presented in our main paper. For now a brief discusssion of toxicology will be provided as an example of the evolution of science and its effects on the need and ability to regulate pesticides.[8]

Toxicity testing and pesticide regulation

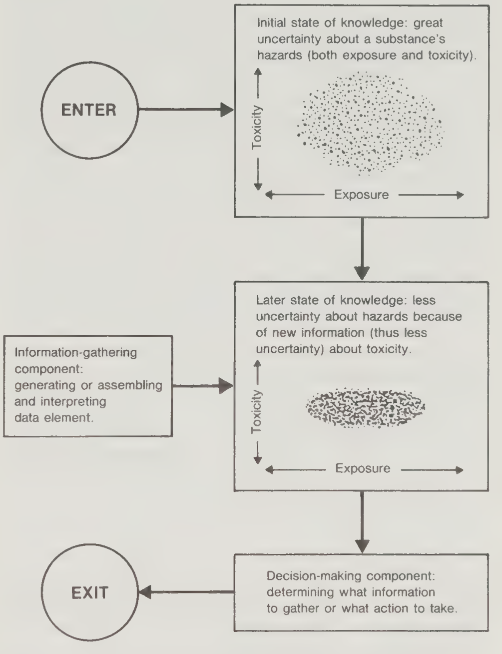
In the 1960s the focus of toxicology was on acute toxicity testing of a few animals to determine lethal doses. Chronic tests to examine longer-term recurring effects were discussed but not typically performed. The principal regulatory concern at this time was with pesticide efficacy and not with secondary effects. With the rise of environmental concern, the continued use of many registered pesticides was called into question because of their newly perceived adverse environmental effects. As a result of improved test procedures, residues could be detected and shown to have adverse effects that, at the time of initial registration, were considered to be a negligible. In the 1970s and 1980s, similar concerns were expressed over the occupational health effects of pesticides. For example, the United States National Academy of Science's review of toxicity test protocols for pesticides indicates that testing for worker safety in terms of neurobehavioral toxicity, dermal toxicity, inhalation toxicity, human sensitization and skin penetration studies have been done inadequately or not at all.

Toxicology advanced from testing at the whole animal level in the 1960s to the cellular and subcellular and on to the molecular level in the 1970s and 1980s. The primary focus of this activity was the refinement of the 'no observed effect level' (NOEL). Orginally this concept was defined in terms of the test animial remaining apparently healthy. Now it refers to no changes taking place at the cell or molecular level. As knowledge increased, scientists developed a new understanding of the effects of toxic compounds and at the same time discovered apparent adverse effects of many compounds previously considered safe. Technological change in the form of better research methods and increasingly precise instruments allowed these advances.

Conceptually the process of registration of chemicals, based upon a given state of knowledge and the regulatory response years later as new knowledge is obtained, can be depicted by Figure 2. However, the process of review, registration and review again based on new information, is easier in theory than in practice. With new information on pesticide hazards and a public outcry for action, both the Canadian and the American governments responded by reversing registration procedures and banning or restricting the use of selected pesticides and other chemicals. In the United States this resulted in the creation of the Environmental Protection Agency (EPA) as the lead agency in pesticide regulation while in Canada the main responsibility was left with Agriculture Canada. Despite the changes that were made in the regulatory structure in both countries to facilitate reviews of existing pesticides, only limited progress has been made. This can be attributed to a number of factors. The review process requires the participation and cooperation of numerous arms of the bureaucracy leading to major coordination problems. A second reason is that the science of toxicology has evolved dramatically over time and new information keeps coming to light which may conflict with previous knowledge. Government regulators are faced with the problem of having the safety of older pesticides, for which there is little toxicity information, being called into question and, at the same time, having to make decisions on hundreds of new chemicals coming onto the market each year.

The science of toxicology gives regulators answers to questions on the basis of the state of knowledge at a particular point in time. Further technological advances that would permit better evaluation of old hazards may, in turn, create new problems for regulators by identifying new problems. It would appear that the level of scientific knowledge is, at the same time, the biggest help and hinderance to the regulator faced with making tough decisions. The only answer at this point is to hope that advances in the science of toxicology will result in clearer evidence for risk assessment so that the process of risk management is made easier for all concerned.[9]

FIGURE 2 EXAMPLE OF ONE STAGE OR BUILDING BLOCK IN PROCESS OF INVESTIGATION AND CONTROL OF TOXIC SUBSTANCES. INFORMATION-GATHERING ACTIVITY HERE IS TOXICITY TEST THAT PRODUCES USEFUL DATA



Source: U.S. National Academy of Sciences, *Toxicity Testing*.

THE ECONOMICS OF PESTICIDE REGULATION: HOW SAFE IS SAFE ENOUGH?

The primary objective of pesticide regulations has evolved from a concern with efficacy to a concern with safety or health effects on humans and other non-target species. Given the inherently toxic nature of pesticides, the limited knowledge of the effects of pesticide use, and the differing level of susceptibility to identical exposures of different individual organisms, it becomes impossible to conceive of a regulatory scheme that could ensure zero probability of adverse effects with a non-zero level of pesticide use.

For most pesticides one can argue that, at the time of initial registration, expected aggregate benefits to society exceed aggregate expected risks; otherwise the registration process has been singularly perverse. However, one can also argue that the registration process does not, and operationally cannot, consider all the factors that would be required to be considered to implement an ideal evaluation.

The distribution of the costs and benefits of pesticide use

The general nature of pesticides is such that the benefits from their use accrue to a large segment of society while the harmful effects tend to be far more concentrated in their incidence. For example, in the case of DDT, society collectively benefited from a reduced incidence of insect-transmitted diseases and lower cost, higher quality food. These benefits accrued directly to a large number of people and were indirectly transmitted to the remainder of society by market forces through changes in relative prices. The cost of DDT use in terms of threats to the survival of non-target species is arguably less sweeping in its incidence but is such that, for certain segments of society, the perceived costs would greatly exceed the benefits.

For an individual in North America who was willing to accept the potential of slightly higher cost or lower quality food, in return for the potential of increased probability of survival of non-target species highly susceptible to DDT, a prohibition on DDT use would be a desirable action. For those members of North American society who placed a higher value on the food effects than the non-target species effects, a ban on DDT is arguably harmful to their welfare. However, when one considers the situation faced in a relatively poor country with a high incidence of mosquito-transmitted malaria, the appropriate decision on the use of DDT is far less clear.

Thus, the basic issue of pesticide regulation requires weighing the incidence of effects, as well as appraising the magnitude of those effects. This requires a recognition that the distribution of benefits and costs is such that the standard methods of economics, which focus on aggregate efficiency and allocation effects without considering distributional effects, cannot be readily applied. Consequently, the first point to recognize in making the decision of how safe is safe enough is that economics can only provide part of the information required to make the decision. A decision to either ban or allow the use of a pesticide will alter the state of well-being of different segments of society in different directions. Thus, no matter what decision is undertaken, some individuals will be better-off than others. The decision as to which segments of society will be harmed and which will receive benefits requires a political and social choice, not an economic one.

This type of differential incidence problem is not uncommon in public policy decisions. Many actions undertaken by governments result in benefits to one group and costs to another. A distinguishing feature of this process within pesticide regulation, however, is that the identification of those benefiting and losing can be exceedingly difficult. Benefits from pesticide use, particularly for agricultural applications, are generally captured within the market system in the form of lower costs-of-production or higher valued outputs. Consequently, these effects are amenable to conventional techniques of economic analysis.

On the other hand, the costs of pesticide use as well as certain benefits fall under the category of unpriced values in the sense that there are no market prices established for loss of life due to pesticide poisoning or for an extended life due to prevention of disease vectors. Additionally, these unpriced values can be discussed only in terms of probabilities of incidence. We may be able to say that the incidence of cancer will increase by three deaths per million in the population as a result of allowing the use of a particular pesticide, but we cannot, *a priori*, say which three individuals. Similarly, if the pesticide reduces death rates by reducing disease transmission, one is even more uncertain of who the beneficiaries are.

The calculation of costs and benefits of pesticide use

A second basic problem of determining how safe is safe enough is the impossibility of determining the incidence of some major costs and benefits. A society that places a uniform value on all individuals may be able to make rational decisions in a collective sense using frequency distributions. In such a society, the actual individuals affected make no difference to the computation of aggregate benefits and costs accruing to that society since all individuals have the same worth. This is not to say that it makes no difference to the individual. In a society that allows for the possibility that different individuals may have different value, an aggregate decision rule based on relative frequencies is inappropriate. The benefits and costs to society now depend upon the particular individuals who are affected by the use of the pesticides. While average or expected values provide a guide for the decision process, they are at best a highly flawed tool for undertaking a cost-benefit analysis in this type of society.

Risks associated with pesticide use

In practice the nature of risks associated with pesticide use break down into three types. First, there are direct exposure risks to human health, associated primarily with those who came into contact with the pesticide in the course of its production, distribution or use. Second, there are indirect exposure risks to human health, associated with residue effects transmitted through food, feeds or water. The third type is environmental risks which have no bearing on human health but alter the quality of life. This latter category may be thought of as an option-demand problem where the members of society must determine the amount they are willing to pay to preserve a particular environmental structure.

In a sense, determining an appropriate level for the first level of risk, that of direct exposure, is the easiest task. Occupational risk is an issue confronted in all work decisions. Provided workers are aware of the risk levels and types of risk they are being exposed to, one can argue that

optimal decisions will be made in terms of those workers who are willing to accept the risks by accepting the job.

Risk of exposure of pesticide workers to hazardous chemicals in the workplace is analagous to occupational hazards of other types. Ashford, in *Crisis in the Workplace*, outlines the problems of determining the economics of occupational hazards. There are problems such as poor information on the hazard and a lack of willingness on the part of business to correct the hazards because it would be a poor investment from the business' point of view. Ashford also argues that "Many workers are socialized to accept the hazardous nature of jobs and are convinced of the necessity of performing them in order to earn their livelihood.... Faced with such conditions, it is hardly surprising the many workers don't want to know (or admit) the risks they are facing on the job."[10]

The second category of human exposure has greater problems since individuals and society are less able to define either the aggregate level of risk or the extent of exposure to the risk. Further, it has been suggested that individuals are willing to be exposed to far lower levels of risk when exposure is involuntary rather than voluntary.[11] For example, individuals continue to smoke knowing that they voluntarily expose themselves to the risk of lung cancer, yet press for the removal of asbestos insulation despite its lower level of risk because such exposure is involuntary.

Concern with indirect exposure has, in the past, exceeded concern with direct exposure. The history of regulatory activity indicates contamination of food and feeds was a concern long before occupational safety issues were raised. This is despite the fact that in absolute magnitudes the degree of risk is far higher for those directly exposed because of both the higher frequency of exposure and greater concentration of pesticide. Such history is consistent with the observation that society is more willing to take the risk if exposure is voluntary than if it is involuntary. Doern notes that "The systematic study of risks has shown, for example, that the public is willing to accept voluntary risks roughly a thousand times greater than those represented by involuntary exposure."[12]

The final concern, environmental risk, is the most difficult to assess in that it results in damages not to humans in a direct physical sense, but to the individual's quality of life. To determine who is harmed by environmental damage requires direct knowledge of how each individual values environmental disruption. In the past, we have relied on physical measures of environmental damage, however, severe measurement problems exist since it is generally difficult to determine the effects of a pesticide on the environment prior to its widespread use due to the complex interrelationships which take place. Moreover, the irreversible nature of some environmental damage may mean that restoration of the environment is impossible. This constitutes a major element of uncertainty in pesticide use which is becoming more problematic as our knowledge increases and creates perhaps the greatest difficulty for the regulator since it is virtually impossible to amass sufficient information to conduct the full environmental impact statement necessary to appraise risks associated with pesticide use. Yet, to do nothing also implies costs to society, so a choice must be made by a regulatory agency.

Risk evaluation

A great deal of literature exists that assesses methods for evaluating risk. A common theme of this material is the impossibility of determining a single level of acceptable risk. Acceptable risk is not a static concept but is one that varies with a number of conditions. Determination of an acceptable level of risk is at the heart of pesticide regulatory activity. Any process that seeks to determine levels of risk must take the dynamic nature of the process into account. At least four major factors influence what levels of risk are acceptable at any point in time.[13] They are: the value structure of society; the available knowledge of the nature, and types of risk; the available alternatives; and the magnitude of the risk.

The value structure of society ultimately determines how the various pieces of knowledge about the benefits and costs of pesticide use are weighed. Such factors as the degree of risk aversion, willingness to allow the imposition of externalities, concern for environmental as opposed to purely financial costs, and the legal and institutional structure of society, ultimately determine the results. As Gillespie et al note in their study of the Aldrin/Dieldrin deregistration decisions in the U.S. and Britain, different outcomes resulted from an evaluation of identical material because the values and processes in the decision-making structure differed.[14] One cannot conclude that the British or the U.S. decision is best unless one adopts the values of one side or the other.

Knowledge of the types and methods of transmission of the impacts of risk will also govern the decision of acceptable risk. Thus, if chronic health effects are discovered after a chemical has been in use for a considerable length of time, this may constitute sufficient new evidence of costs for society to reverse its decision to allow a particular use of the chemical. As the technology or body of knowledge underlying toxicology, environmental science and other disciplines that trace the impacts of pesticides develops, our knowledge of the effects of pesticide use is enhanced and previous decisions may be revised.

The third element affecting the decision of how safe is safe enough has to do with available alternatives to either the chemical in question or substitute products. In the case of a chemical that we discover to have harmful effects, the decision to revoke its use is easier if an alternative chemical exists that provides similar benefits at lower costs. Alternatively, if we find a substitute end product or process that obviates the need to use the chemical, then the decision to increase production costs of the orginal product by banning a chemical used as an input, imposes relatively low costs on society.[15]

Finally, the magnitude of the effect can have a bearing on the decision. If pesticide impacts follow a threshold effect or some sort of logarithmic growth curve, then low levels of exposure may have no detectable influence on the environment or man. In such a case the natural assimilative and detoxification processes of the human body and the environment are capable of dealing with low levels of exposure, and a decision to allow such uses is reasonable. If use expands to the point where the capacities to assimilate and detoxify are exhausted, the decision to allow use could be expected to change.

CONCLUSION

It is clearly beyond the scope of this article to determine how these four elements should be incorporated into the decision of how safe is safe enough or how much to regulate. They do, however, need to be incorporated if only in the sense of making the assessment of risks and benefits of particular chemicals an iterative process. Risk-benefit analysis, and the resulting regulations, constitute a dynamic process which takes into account the introduction of new technology, be it in the form of new chemicals, new chemical uses, new knowledge of the effects of chemicals, or new products or processes that indirectly affect the demand for chemicals. In addition, this process must also take into account the changing nature of society as institutions and social values evolve. As noted in the first section, it would seem that any process that allows the use of pesticides will, by necessity, expose people and the environment to risk. However, failure to allow the use of pesticides can be shown to impose costs on society including, for a number of pesticides, health risks to humans.

In a statistical sense, appropriate processes for conducting carcinogenicity and other toxicity tests are only being determined now.[16] Consequently, the probablity of errors in accepting or rejecting particular hypotheses concerning the effect of chemicals on human health are not well developed.

McCarey notes that "The fact remains, however, that risk-benefit assessment may result in registration of carcinogenic pesticides... The fact that risk-benefit assessment does not lead to an 'objective' decision, and may even lead to a different result depending on the decision maker, does not render the process useless. The statutory mandate that risks and benefits be taken into account requires at the very least that the decision maker consider factors on both sides of a decision. To the extent that factors can be quantified, the decision is made more objectively. Neither Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) nor EPA regulations require quantification of all aspects of the decision. Their only mandate is that risks and benefits be considered and weighed in the decision-making process. The balancing process would result in a public perception that pesticide decisions are made in a manner fair to all interested parties and will thus lead to greater acceptance of the agency's decisions".[17]

As a result, not only is risk-benefit analysis itself a statistical concept where the particular choice of distributions of benefits and costs determines the results, but given the lack of knowledge about these underlying distributions the conclusions drawn are themselves random variables with unknown variances. Given the feedback effects which regulation and technological change have upon each other, it is highly likely that errors made in the risk-assessment process for a particular compound can result in changes in technology and regulations which are undesirable. Nevertheless, regulatory activity must proceed since the cost of delay can be as great as the cost of wrong decisions. In dealing with this dilemma it is important that the registration process be open to new information as it becomes available. A process of periodic review, although costly and time consuming, would seem to be necessary to accomplish this task.

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[1] Dr. David Freshwater is an associate professor of agricultural economics, University of Manitoba. He is currently on a temporary leave of absence and is working with the United States Department of Agriculture. Grant Wichenko is a professional engineer with Appin Associates, Winnipeg, Manitoba.

[2] Metcalf, R. (1964), Methods of Estimating Effects. *Research in Pesticides*. p. 18.

[3] In addition to domestic regulation, the Canadian market is also influenced by regulatory activity in the United States, the single largest market in the world. The cost of developing and registering a compound solely for the Canadian market precludes such an action. Both chemical companies and the Canadian government rely on information generated in the U.S. registration process to reduce the cost of Canadian registration. Consequently, changes in the U.S. regulatory structure may also affect Canadian procedures.

[4] Ashford, N., et al (1979), *Environmental/Safety Regulation and Technological Change in the U.S. Chemical Industry*. MIT. p. ES-5.

[5] Ibid., p. ES-7.

[6] Scherer, F.M. (1980), *Industrial Market Structure and Economic Performance*. Chicago: Rand McNally.

[7] Freshwater, D., K. Gibson and R.M.A. Loyns (1983), *Retail Herbicide Prices in Manitoba and North Dakota*. Report to Consumer and Corporate Affairs Canada.

[8] This discussion is based upon a survey of toxicology literature conducted by the authors to establish the evolution of the science.

[9] For a discussion on the merits of separating "scientific" and "policy" decisions, readers are referred to the United States Office of Technology Assessment's (USOTA) (1983), *Technologies for Determining Cancer Risks from the Environment*, p. 14-15, and T. Shrecker's (1984), *Living with the Inescapable: Risks and Benefits of Pesticide Policy*.

[10] Ashford, N. (1976), *Crisis in the Workplace*. MIT Press. p. 358.

[11] Fischoff, G., et al (1981), *Acceptable Risk*. Cambridge University Press. p. 81. See also USOTA (1983), *Technologies for Determining Cancer Risks from the Environment*. p. 218.

[12] Doern, G.B. (1982), *The Politics of Risk: The Identification of Toxic and Other Hazardous Substances in Canada*.

[13] The USOTA study, *Technologies for Determining Cancer Risks from the Environment*, lists the following factors: level of hazard inherent in exposure to the chemical; types of exposure which create the hazard; populations likely to be exposed; extent of the exposed populations; whether the exposure would be voluntary or involuntary; availability of substitutes; the worth to society of continued availability of the substance; cost inherent in various levels of control or elimination; nature of the data suggesting the existence of a hazard; ability to extrapolate from those data to predict the hazards in other situations and relative importance of regulating the particular chemical in view of the risks presented by as-yet-unrelated chemicals. p. 217-8.

[14] Gillespie, B., et al (1979), Carcinogenic Risk Assessment in the United States and Britain: The Case of Aldrin/Dieldrin. *Social Studies of Science*. Vol. 9.

[15] For example the cost of deregistering 2,4,5-T is arguably reduced because substitute chemicals exist that can perform much the same function. See our main paper, Chapter V, for more detail.

[16] See for example, McKnight, B. and J. Crowley (1984), Testing for Differences in Tumor Incidence Based on Animal Carcinogenesis Experiments. *Journal of the American Statistical Association*. See also the November issues of the *American Statistician* on Statistics and the Environment.

[17] McCarey, W. (1977), Pesticide Regulation: Risk Assessment and Burden of Proof. *The George Washington Law Review*. Vol. 45, No. 5.

IN REPLY TO AUTHORS AND EDITORS REGARDING VOL. 20 NO. 1

Canadian Farm Economics

I have read	*and on a scale of 0 to 10, found it* *not useful* — *very useful*
The economics of feeder cattle and calf pricing in North America	0 ____ 5 ____ 10
Canadian stabilization initiatives and their effects on the welfare of American pork producers	0 ____ 5 ____ 10
Developments in the Canadian beef and cattle market during 1984	0 ____ 5 ____ 10
Coming to grips with pesticide regulation	0 ____ 5 ____ 10

Comments on (name of article)

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CONVERSION FACTORS

Metric units	Approximate conversion factors	Results in:
LINEAR		
millimetre (mm)	x 0.04	inch
centimetre (cm)	x 0.39	inch
metre (m)	x 3.28	feet
kilometre (km)	x 0.62	mile
AREA		
square centimetre (cm^2)	x 0.15	square inch
square metre (m^2)	x 1.2	square yard
square kilometre (km^2)	x 0.39	square mile
hectare (ha)	x 2.5	acres
VOLUME		
cubic centimetre (cm^3)	x 0.06	cubic inch
cubic metre (m^3)	x 35.31	cubic feet
	x 1.31	cubic yard
CAPACITY		
litre (L)	x 0.035	cubic feet
hectolitre (hL)	x 22	gallons
	x 2,5	bushels
WEIGHT		
gram (g)	x 0.04	oz avdp
kilogram (kg)	x 2.2	lb avdp
tonne (t)	x 1.1	short ton
AGRICULTURAL		
litres per hectare (L/ha)	x 0.089	gallons per acre
	x 0.357	quarts per acre
	x 0.71	pints per acre
millilitres per hectare (mL/ha)	x 0.014	fl. oz per acre
tonnes per hectare (t/ha)	x 0.45	tons per acre
kilograms per hectare (kg/ha)	x 0.89	lb per acre
grams per hectare (g/ha)	x 0.014	oz avdp per acre
plants per hectare (plants/ha)	x 0.405	plants per acre

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Contents

The on-farm economics of sustainability and public intervention

J. Girt[1]

Although there is a growing realization among producers and policy makers of the serious nature of agricultural soil degradation in Canada, the design of options to address the problem is more difficult than the identification of the problem itself. A successful soil conservation policy must take into account the national and regional economic significance of degradation in order to place realistic upper and lower limits on public expenditures. At the same time, it must be sensitive to the microeconomic effects of both degrading and more sustainable production practices on the farm business, to provide realistic economic incentives to farmers to conserve soils.

This article lays out some broad, economically based principles in the Canadian context which would allow this integration of macro- and micro-level concerns. Farmers would then have an economic incentive to control or avoid degradation appropriate to the market conditions for their commodities, while serving public interest by avoiding detrimental off-farm effects of soil degradation. The off-farm effects would include such public costs as dredging, chemical pollution of surface waters and loss of wildlife habitats, as well as the public impacts of reduced economic productivity on the farm.

The risk of soil degradation varies according to soils, climate and type of land use. Similarly, options for its control vary considerably and from farm to farm. Soil and water policy then has to focus on providing a supportive environment for the individual producer to decide what the "best use" of land would be.

NATIONAL ECONOMIC IMPACT OF SOIL DEGRADATION

Although there are some discrepancies between studies of the economic impact of soil degradation on agriculture, they are sufficiently close that one can argue that all are probably close to the mark.[2] Two recent studies sponsored by Agriculture Canada provide a national estimate of $698-915 million for on-farm effects in 1984.[3] These consist of assessments of the value of reductions in yields and increases in input costs, particularly fertilizer, attributable to the soil degradation said to be occurring as a consequence of soil characteristics and cropping patterns across Canada. Although these assessments do not allow for some possible double counting between different types of degradation, the lower limit is conservative.

The national economic impact of this amount of degradation can best be illustrated through its effect on value added or Gross Domestic Product (GDP). GDP for the farm sector consists of net farm income before depreciation, interest payments, rent payments and wages paid. It measures how much greater the value of the farm output is than the value of purchased inputs (excluding land). The estimates of the impact of soil degradation on farm GDP are shown in the table. In 1984, national GDP for the sector was reduced almost 10%. Most, if not all, of this loss would have been from farm incomes. Alternatively, it can be argued that the avoidance of soil degradation would have increased farm GDP by $1 billion, less the costs of avoidance.

ESTIMATES OF THE IMPACT OF SOIL DEGRADATION ON FARM GROSS DOMESTIC PRODUCT (GDP) ($ MILLIONS)

Region	Agriculture GDP — 1984	Estimated on-farm costs of soil degradation in 1984	Estimated percentage reduction in agricultural GDP attributable to soil degradation in 1984	Percentage of 1984 national degradation costs
British Columbia	583	22-25	4	3
Prairies	4 483	472-609	9-11	68
Ontario	2 689	140-193	5-7	20
Quebec	1 285	37-48	3-4	5
Atlantic	352	27-40	7-10	4
CANADA	9 752	698-915	7-9	100

Provincially, the effect of soil degradation was particularly severe in Alberta, Saskatchewan, New Brunswick and Prince Edward Island.

This static picture may be somewhat misleading because rates of degradation may change and because it is too easy to equate effect of degradation with potential impact of amelioration. Much of what has been degraded cannot be replaced within a generation, except at considerable cost. However, the time and production systems required to restore land quality are not known with any certainty, though response times will be much longer in drier and colder regions than in more humid and temperate ones.

Pessimistically, for the prairies, it would seem that expected market conditions for grains and long response times could not support widespread land rehabilitation over a protracted period. With this in mind, publicly funded control may have to be aimed at preventing further degradation. In eastern Canada and British Columbia the situation is less clear and some rehabilitation may be economically justifiable.

Finally, and most importantly for public policy development, the impact of soil degradation on the non-agricultural sector of the economy has not been considered in the table. The information on externalities of degradation is very weak; however, there are indications that for certain regions, at least, external costs of agricultural degradation are almost as significant as those for the farm sector. One preliminary assessment estimates the off-farm costs in Ontario to be more than 60% of the on-farm costs.[4] Such information implies that the total national public and private costs of agricultural soil degradation may approach $1-1.4 billion or 12-13% of agricultural GDP in 1984.

In aggregate terms, the impact of degradation costs is greater in the case of farm income than value added, as we can assume that soil degradation primarily affects the farm income component of value added. Nationally, net income from farming is approximately one half of value added from farming. Why then does soil degradation not generate more concern among farm lobby groups?

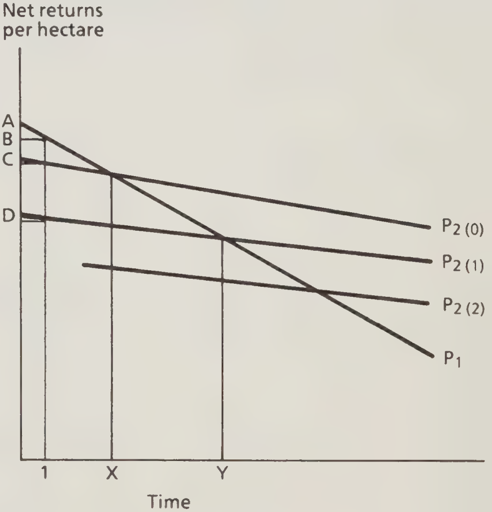
Part of the answer, no doubt, lies in the insidious nature of soil degradation. One can argue that farmers have managed to maintain or improve productivity in spite of soil degradation. Profitability or returns may have been eroded but not to the extent suggested by the effects of soil erosion. Knowledge that degradation is occurring may not be available, or may not be credible, and does not necessarily lead the economically rational producer to adopt more sustainable production methods. In many cases, undoubtedly, costs of avoiding degradation exceed the benefits that will accrue.

MICROECONOMIC IMPACTS

Earning a living from a degrading or shrinking resource base is not a comfortable experience. However, if producers are to maximize returns and their cash flows, the adoption of more sustainable production practices (other things being equal) will be an elusive goal. This will invariably be the case unless net returns from conserving production practices equal or exceed returns from more degrading practices within a short time of adoption. Given that conservation practices frequently require more inputs and/or give lower output over the short term, finding those that will pay within the planning horizon of many farmers is a considerable challenge.

Consider Figure 1, where the net returns from a degrading production practice (P_1) are shown declining at a faster rate than a series of net return curves for a less degrading practice (P_2). At time 0, a producer will lose earnings by adopting the less degrading practice represented by $P_2(0)$. By selecting the degrading practice for year 1 the producer will be facing a decline in earnings of AB. However, the less degrading practice, adopted at this time, lowers income even more (AD), and returns will only exceed those from the more degrading one by time Y. Had the producer adopted the less degrading practice a year earlier, returns would have surpassed those for the degrading practice by time X.

FIGURE 1 COMPARISON OF RETURNS FROM MORE AND LESS DEGRADING PRODUCTION PRACTICES



The goal of conservation remains elusive, and will continue to be so into the future according to this model unless the farmer is willing to forgo some income now in the expectation of improved returns later. There are indications that farmers' time horizons in this respect are quite limited, particularly with high levels of debt, low commodity prices and increasing input costs. Further, there is a growing body of literature citing many social, as well as economic, factors influencing rates at which farmers adopt conservation practices.[5] Addressing non-economic factors will frequently require expenditures to overcome these constraints, or economic incentives to overcome their negative effects.

The strategy required to address non-economic factors, as well as the purely economic one examined through Figure 1, have been examined in welfare economics under the issues of market failure[6] and intergenerational transfer of benefits and costs.[7]

Under conditions of market failure, the true costs of degradation will not be taken into account in farmers' decisions for reasons such as:

- lack of information about the impact of farm production decisions or all the optional practices available;
- dependency on other agencies, particularly public ones, for research and development of new cropping production alternatives;
- off-farm effects of degradation not reflected in on-farm production costs; or,
- existing policies that inadvertantly discourage conservation — for example, pesticide policies that affect herbicide prices.

The intergenerational transfer issue can be examined at two levels. At the level of society it concerns the issue of whether and to what extent present producers should be expected to adopt conservation practices for the future benefit of other producers and the public in general. At the level of the individual, the issue is whether costs should be incurred now for conservation that will realize benefits spread over time.

Incentives and penalties

A soil degradation policy should then be concerned with how to best use public resources for the optimal pattern of land use with respect to the agricultural industry's contribution to the economy. A policy based purely on the physical aspects of land use cannot be a desirable end of government policy unless it maximizes community welfare. Likewise, a policy based purely on reducing the previous costs of degradation may have a minimal or even negative impact on community welfare now or in the future.

For a policy to maximize community welfare, two conditions must be met. First, the market failure and intergenerational issues must be identified and addressed. Second, the expected benefits of the policy must exceed its costs and the affected producers should also receive the appropriate returns for their participation.

Governments have three basic tools available to use in policy development. Incentives are expenditures designed to remove the effects of the two degradation issues (market failure and intergenerational transfer). They are positive inducements that reduce costs or raise revenues to improve net returns from conservation practices, etc. Penalties and regulations are the opposite, being ways to discourage or ban degrading practices.

Some carefully planned mixture of all three tools may be necessary for a policy to be most effective. For obvious reasons, incentives are more frequently promoted than disincentives, so we will begin with an examination of them.

Incentives may address the question of intergenerational transfer. In other words, they reward producers driven by short-run economic considerations for their increased costs for maintaining the soil base for the future. There are considerable difficulties in estimating what this payment should be.

It is difficult to focus incentives so that they do not encourage over-investment or over-adoption. Where they are used to reduce producers' costs of repairing their land, unless the incentive is sufficient to place a conserving practice's net return immediately above that for a degrading practice, it may have the opposite effect than intended. To the producer the subsidy may have the effect of lowering the penalty of degradation, as the repair costs have been reduced, and reducing the significance of the degradation.

Competing demands for public funding will often realize higher short-term benefits than conservation incentives, particularly when there is no evidence that food supplies are being threatened by Canadian land degradation. It can also be argued that with the current government deficits, all one has done by paying incentives, in the absence of expenditure cutbacks to other government programs, is to force future generations to pay for an increased deficit rather than a less productive land base. If existing programs are cut back, we may have accomplished little more than making today's producers poorer and future generations relatively richer.

In Figure 2, a more degrading practice is represented by the net return curve AI, and a less degrading one by CG. An incentive equivalent to the per-farm share of the off-farm degradation costs brings CG up to BF. Assuming that farmers now adopt the less degrading practice, the cost to society of this action to time L is BFGC. The gain to producers of making the switch is DFI less ABD, assuming that the change in production is made at time O. The public benefit of this change will be part of the private gain, and a considerable part of the private gain is made up of the continuing public subsidy or cost, BFCG. Whether it is in the public interest to pay the incentive to time L depends on public discount rates. However, it is clear that L needs to be clearly defined and the incentive sunsetted.

During the period when an incentive is being paid to producers to adopt less degrading practices, it is unlikely that public benefits will exceed public costs of the incentive. Unfortunately, there may be no compelling economic reasons for producers to continue with the less degrading practices when the subsidy is removed, in the absence of a penalty on degrading uses.

In Figure 3, a penalty is introduced on the net return curve AG, representing degrading practice. Like the incentive, this penalty, reflecting the immediate off-farm costs of degradation on a per-farm basis, would result in a new net return curve of BH. With no compensation payment, producer returns from switching to the less degrading practices will be EFG less ACE, at no continuing cost to society apart from any necessary short-run adjustment support to producers making the switch.

If we assume that the off-farm costs are equally proportionate to both areas BFGC and ABHG in the respective scenarios, we can see that in the first case, society does not profit as much because it used a subsidy to producers similar to the cost of the off-farm effects. In the second case, the off-farm effects are removed at no continuing public costs, but at costs to the producers. Obviously some combination of the two adjustments is required if government is to address market failure. In Figure 3 this would imply a temporary subsidy on net returns from the less degrading practice to move it from CF to closer to AEF — or a total public subsidy of approximately ABDE.

Thus, from a public perspective it would generally be most efficient to induce production change in support of more sustainable agriculture by integrating:

- development of improved production practices that bring short-run net returns equal to or greater than the net returns of more degrading ones, less the costs of off-farm degradation;
- promotion of these new practices combined with increases in production costs for degrading practices that reflect their off-farm effects and other public costs — the actual means chosen could include differential land taxes based on land use and zoning sensitive to degradation risk. In some cases a banning of specific practices could be considered. However, in other industries regulations have not proven as effective as price incentives;[8]
- public support for temporary shortfalls in income associated with a move to less degrading practices equal to or less than the public benefits associated with the change. Alternatively, such payments could be regarded as compensation for zoning changes; and
- public expenditures not exceeding public benefits that will accrue, using the current government opportunity cost of capital as the discount rate.

FIGURE 2 THE EFFECT OF A SUBSIDY ON NET RETURNS

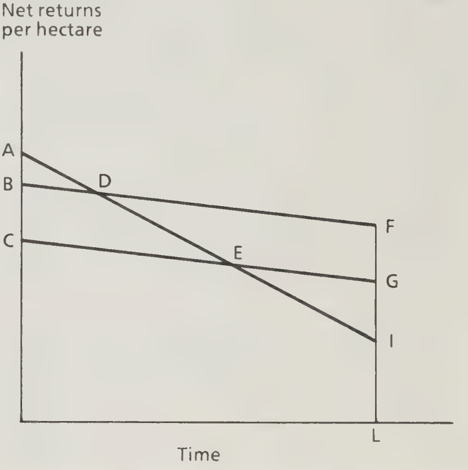
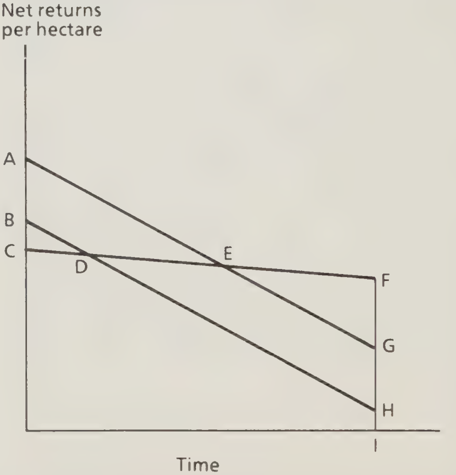


FIGURE 3 THE EFFECT OF A DEGRADATION PENALTY ON NET RETURNS



Failure to integrate all these activities will weaken their effectiveness considerably.

So much for the theory, but what of the practicality? The effectiveness of the system depends on two factors: first, the degree to which costs of sustainable production practices can converge and become competitive with those of degrading practices within the planning horizons of farm operators; and second, the quality of information provided to farm operators on the economics of alternative production systems, the ease with which they can change from one system to another and the risks involved. This is a real information void that should be filled quickly.

On the first consideration, evidence is accumulating that soil conservation can pay, providing a method is found of applying non-private degradation costs to the farm sector. Two recent studies have estimated the expected annual net returns using current prices for various cropping options in central Canada[9] and Alberta.[10] In each case, degrading practices provided a greater short run net return than other practices. In the case of the Alberta study, this difference was maintained over the medium and even the long term. A number of cropping options in a number of different degradation risk zones are considered in the reports, and by way of examples, some are shown in Figures 4 and 5 for Ontario and Quebec.

The off-farm costs of degradation itself have been estimated at approximately $100 million annually in Ontario. Total public costs, which would also include the public effects of the farmers' annual losses attributed to soil degradation, will, of course, be greater than this. However, by way of illustration, these $100 million costs can be attributed to the 20% of Ontario cropland currently considered under risk of degradation. The equivalent per-hectare cost on these vulnerable lands is approximately $10/year. The impacts of applying this cost as a penalty to private net returns from the degrading practice in the Ontario and Quebec examples are shown in Figures 4 and 5. The more sustainable production practices have become more attractive short-term investments.

In the Quebec example, the analysis indicates that no incentive for adoption should be necessary after the imposition of this penalty. In fact, one has to wonder why, if the analysis behind this example is correct, some farmers continue to avoid zero-tillage operations in this part of Quebec. Should there be some adjustment costs in making the switch from fall plowing practices, any public support should be within the bounds examined in the next example from southwestern Ontario involving the same practices, but on a sandy/loamy soil.

In the Ontario situation, the economic feasibility of making the switch to the less degrading practice is not so favorable from both a public or private perspective. Using the $10/ha estimate of annual public costs of degradation as a penalty only makes the less degrading practice, if adopted in year one, more profitable than the degrading one after 10 years. Realistically, there is still little incentive for the producer to adopt. Public savings from the adoption of the less degrading practice are unlikely to be sufficient when converted to a farmer incentive to change this conclusion. For example, were off-farm costs to begin to decline after 5 years at such a rate that in 20 years they

FIGURE 4 COMPARISON OF NET RETURNS FROM CONTINUOUS CORN UNDER FALL PLOWING AND ZERO-TILLAGE CULTIVATION, CLAY SOIL, 9% SLOPE, SOUTHWEST QUEBEC

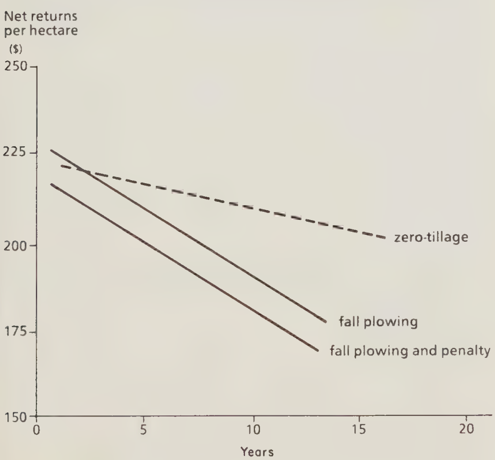
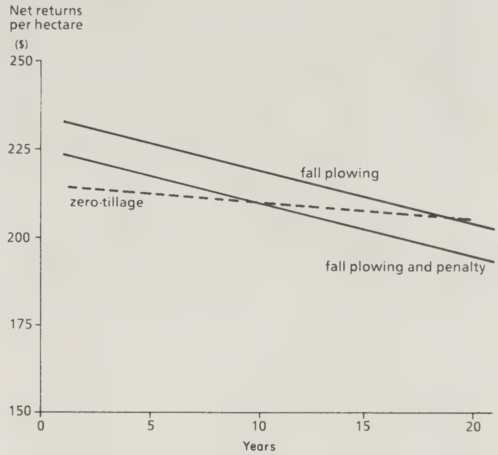


FIGURE 5 COMPARISON OF NET RETURNS FROM CONTINUOUS CORN UNDER FALL PLOWING AND ZERO-TILLAGE CULTIVATION, SAND/LOAMY SOIL, 6% SLOPE, SOUTHWESTERN ONTARIO



would be only one-quarter of the rate in year one, public savings, using a discount rate of 10%, would be $11.65/ha compared to public costs of a 10-year incentive program, using the same discount rate, of $42. Only in the unlikely situation that off-farm costs immediately began to decline and disappear after 5 years, would total benefits exceed total costs. By way of comparison, the $11.65/ha savings of the more likely scenario would support a 10-year incentive payment in Quebec of $2.75/ha, sufficient to make the incentive a reasonable public investment.

In the Alberta study, results indicate a relatively small, but longer lasting, per-hectare difference in net returns between more- and less-sustainable practices. Estimates of public costs of degradation are not currently available. However, the per-hectare off-farm costs of degradation are likely smaller in this region because of the lower population density and, consequently, less geographically intensive infrastructure.

CONCLUSIONS

Although a number of recent studies have demonstrated that soil degradation does have significant economic impacts, they have not given clear estimates of the potential economic gains from programs to control the problem. The on-farm costs and revenues of alternate production practices and their associated rates of degradation need to be collected or estimated in degradation-prone areas. Decisions on programs to encourage feasible production and associated penalties could then be made, subject to local commercial production alternatives.

Administration of a system to apply the public costs or benefits of avoiding public costs of degradation back into the private system will depend on the support of all levels of government. Provincial responsibilities for the regulation of land use must form the legal basis of any policy to discriminate between farms on the basis of land use (cropping system) and physical land characteristics. The research necessary to identify the private and public costs will involve many public and private organizations. The regulation of land use, or the imposition of a penalty for the use of a specific cropping practice, would best be left to municipal or conservation authorities. On the other hand, programs to encourage the adoption of new practices may, depending on the target population, be administered by any level of government.

Administration of a system does not appear to present as many technical difficulties as determining the public costs and the way to charge these back as penalties and incentives to the farm sector. This article has presented an outline of a system that would allow costs of avoidable degradation over time to be reflected in the immediate- and medium-term financial situation of the farm business, without any public subsidy in the medium to long term. It represents an attempt to integrate the environment and economics without bias in terms of who should shoulder the burden of degradation — the operator or the public, or present or future generations. In the absence of a research breakthrough that makes soil-conserving cropping systems immediately the most profitable, some reallocation of costs and benefits along the lines presented will be the cheapest way of preventing avoidable degradation, and putting agriculture on a more environmentally sustainable path.

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[1] John Girt is director of Sector Performance and Natural Resources Division, Agriculture Canada.

[2] See Agriculture Canada (1985) *Agricultural Soil and Water Resources in Canada: Situation and Outlook*, Ministry of Supply and Services (copies are available on request from the author), and Rennie, D. (1985), Implications of Present Situation and Outlook for Agricultural Natural Resources in Canada, published in Agriculture Canada, *Proceedings of the Canadian Agricultural Outlook Conference*, December, 1985, available from Services Division, Agriculture Canada, Ottawa K1A 0C5.

[3] Anderson, M. and L. Knapik (1984), *Agricultural Land Degradation in Western Canada: A Physical and Economic Overview*; and D.C.H. Consulting and Land Resources Research Institute (LRRI) (1985), *A Preliminary Economic Assessment of Agricultural Land Degradation in Eastern and Central Canada, and Southern British Columbia*. Both studies are published as working papers of the Regional Development Branch, Agriculture Canada, and copies are available on request from the author.

[4] See the D.C.H. and LRRI study (footnote 2)

[5] See, for example, Culver, D. and R. Seecharan (1986), Overview of the Factors that Influence the Adoption of Soil Conservation Technologies. *Canadian Farm Economics*, Vol. 20, No. 2.

[6] Bator, F.M. (1985), The Anatomy of Market Failure. *Quarterly Journal of Economics*, Vol. 72, pp. 351-379.

[7] There is a large amount of literature on the intergenerational issue. See in particular Pigou, A.C. (1932), *The Economics of Welfare*, London; Peterson, F.M. and A.C. Fisher (1977), The Exploitation of Extractive Resources: A Survey, *Economic Journal*, Vol. 87, pp. 681-721; and Fisher, A.C. and J.V. Krutilla (1975), Resource Conservation, Environmental Preservation and the Rate of Discount, *Quarterly Journal of Economics*, Vol. 89, pp. 358-370.

[8] Stewart, R.B., Economics, Environment and the Limits of Legal Control in B. Sadler (ed) (1985), *Environmental Protection and Resource Development: Convergence for Today*. University of Calgary Press.

[9] Seecharan, R., D. Culver and D. Murray (1985), *A Preliminary Economic Evaluation of Soil Conservation Technologies in Central Canada: Implications for Agricultural Development*. Working paper, Regional Development Branch, Agriculture Canada. Copies are available on request from the author.

[10] Narayanan, A.V.S. (1986), Long-term on-farm economic effects of cropland erosion in the black soil zone of Alberta. *Canadian Farm Economics*, Vol. 20, No. 2.

Factors that influence the adoption of soil conservation technologies

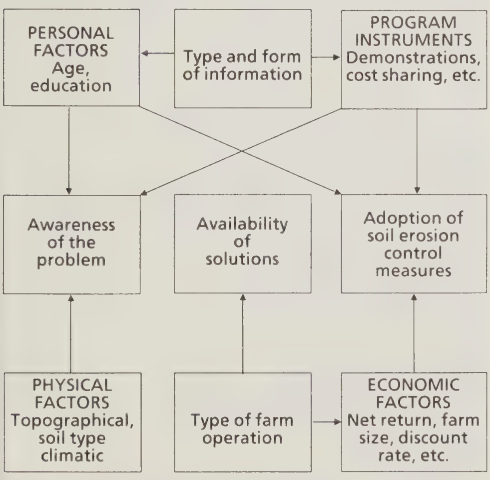
D. Culver and R. Seecharan[1]

The future of Canada's most important resource base, soil, is at risk as a result of excessive erosion. Caused by water and wind, erosion can deteriorate the productivity of the land base and, in some extreme cases, agricultural use of the land can be lost completely. While soil erosion is a problem in all regions of Canada, its severity varies between regions.

Despite the significant on-farm costs associated with soil erosion (Girt, 1986), adoption rates of many conservation practices, particularly conservation tillage systems, are very low. In the prairies, zero-tillage is used on about 10 000 ha in each province. In central and eastern Canada the moldboard plow is by far the most widely used tillage implement. For example, a survey conducted in 1984 in southwestern Ontario showed that 55% of the total recorded farm area was moldboard plowed in the fall (Wall, et al, 1985).

The reduction of on-farm costs associated with soil erosion depends largely on the increased adoption of soil conservation practices. This article provides an overview of the factors that influence this adoption. The major factors and the relationships between them are outlined in the model.

MODEL PORTRAYING HOW VARIOUS FACTORS INFLUENCE THE ADOPTION OF SOIL CONSERVATION TECHNOLOGIES



Source: Modified from Ervin and Ervin, 1982

AWARENESS OF THE PROBLEM

The adoption process begins with the recognition of the erosion problem. Farmers who do not believe they have a problem will not take action to alleviate it. Their awareness of the problem depends on a number of factors, including government program instruments and personal characteristics of the farmers such as age and attitude towards risk.

In Canada, farm organizations, universities, governments and other groups have convinced many farmers that soil erosion is a serious problem. In 1984, approximately 56% of farmers in southwestern Ontario believed they had a water erosion problem on their own farms (Wall, et al, 1985).

However, farmers are not always aware that erosion is *their* problem. Evidence in the United States suggests that their general awareness of soil erosion is much higher than their awareness of erosion problems on their own farms. In a survey of 112 of the most erosive counties in the United States, 92% of farmers perceived erosion problems in the county, whereas only 66% perceived erosion to be a problem on their farms (Bultena, et al, 1984). Studies (Nowak, 1985) in Nebraska and Iowa found that the majority of the farmers who did not believe they had an erosion problem actually had one.

In addition to being aware of erosion, farmers must also be aware of the extent to which it affects their net income now and in future. Today, however, they face other problems, such as high debt and low income, that they may perceive as more significant. Under these circumstances, action will only be taken if farmers view the problem of soil erosion as a priority and are financially able to make adjustments.

PHYSICAL FACTORS

Control of soil erosion to achieve desired conservation goals is related to land characteristics. Soil is not homogenous and, as such, general recommendations without accounting for differences in topography, soil and climatic conditions may result in failure or inappropriate use of a conservation measure. Even within a farm, differences in soil characteristics may require a variety of measures. In central and eastern Canada, clay soils limit the use of certain tillage practices whereas, in the prairies, inadequate rainfall limits the use of extended rotations. Existing physical restrictions such as soil drainage, stoniness, or small farm size were listed by 6.1% of farmers in southwestern Ontario as the reason for not adopting new practices (Wall, et al, 1985).

Studies by Timmons and Fischer (1963) in Iowa, Coughenour and Kothari (1962) in Kentucky, and Carlson, et al, (1981) in Idaho have indicated a positive relationship between farm size and adoption of soil conservation measures. This may occur because operators of larger farms have more flexibility in their decision-making, better access to capital and the opportunity to experiment with new conservation practices on a small portion of their farms. Moreover, high fixed costs for control measures can slow the rate of adoption on smaller farms. Further, Wagener, et al, (1981) suggested that operators of larger farms are better able to deal with the risk and uncertainty often associated with new agricultural practices.

The concept of a relationship between farm size and adoption of soil conservation practices is not unanimous. Buttel, et al, (1981) found a negative relationship between farm size and adoption. These researchers maintain that operators of large farms are likely to create or ignore erosion problems compared with operators of smaller farms since large farm machinery is often incompatible with many conservation practices.

ECONOMIC FACTORS

The actual and perceived economic returns of conservation practices are a major reason for their low adoption rates. Unlike most other agricultural technologies, the economic benefits often do not accrue immediately after adoption, but several years later. Also, the economic benefits are uncertain and this makes it difficult for farmers to make rational economic decisions on adoption. Future erosion rates, commodity prices, input prices and technological developments will all influence the profitability of conservation and non-conservation systems. Uncertainty also arises since the economics of many conservation practices depend on unique farm characteristics such as soil type and slope length.

The economic assessment of a conservation farming system should be based on the present value of the discounted income with conservation tillage as opposed to a non-conservation system. The net present value of conservation practices depends on a farmer's planning horizon, discount factor, annual net profits and the resale value of land. The planning horizon will depend on such factors as the operator's age and intentions to transfer the farm to another family member. In general, the longer the planning horizon the more favorable will be the economics of conservation practices. An appropriate discount factor depends on such factors as alternative investment opportunities and interest rates.

The discounted income will also depend on the annual net profit with conservation tillage as opposed to a non-conservation system. As the productivity of the soil is improved or maintained, conservation systems often result in a higher net profit in the longer term. However, on a discounted basis, profits in the future are of less value to the farmer than profits immediately after adoption.

The resale value of land also affects the discounted income. If land that has been properly managed has a higher resale value than that not properly managed, farmers would have an additional incentive to adopt conservation measures. Some current evidence indicates that farmers pay little or nothing more for land that has been properly managed. Interviews undertaken by the Conservation Foundation in the United States concluded that almost no premium is paid for land on which permanent conservation practices have been introduced or on which the soil has been carefully husbanded (Batie, 1984). The lack of a premium on properly managed land reduces the economic incentives of conservation practices and, therefore, adoption rates.

In addition to the net present value of income, the level and source of income also appear to be correlated with the adoption of soil conservation farming practices. Lasley and Nolan (1981) found that farmers who tend to cooperate with soil conservation organizations have slightly higher incomes than non-cooperators.

Farm debt may influence the adoption of soil conservation measures in two ways. First, to pay off high debts (e.g., land mortgages), operators are forced to plant high-value row crops that leave a significant portion of the soil exposed throughout the growing season. Secondly, farmers with high debts find it difficult to finance conservation measures. Blase and Timmons (1961) found that the majority of farmers (60%) surveyed cited debt servicing as a major obstacle to adopting conservation practices in western Iowa.

Access to capital in the form of accumulated savings or capital markets is necessary to finance adoption of some erosion control practices. Thus, differential access to borrowed capital is often cited as a factor affecting adoption rates, especially for those measures requiring large investment. In Canada, a number of farm credit programs are available to farmers, however, the availability and eligibility requirements vary significantly between provinces.

The farmer's tenure may also be significant to the adoption of erosion control measures. Early studies (Frey, 1952) have found that tenancy arrangements are very important in explaining adoption or non-adoption. Since then, Dillman, et al, (1978), Ajaga (1980), and Schertz and Wunderlich (1982) have found similar relationships. Owners, unlike tenants, tend to employ control practices because they are likely to reap long-term economic benefits. Further, owners are likely to benefit directly from economic incentives associated with conservation practices (Cook 1981). In North America, this relationship between tenancy and soil conservation is the result of tenants rarely being compensated for land improvement or penalized for land degradation.

PERSONAL FACTORS

Several studies, including those by Swanson (1974), Hoover and Wiitala (1980), and Lasley and Nolan (1981), have shown that age of the operator is related to the adoption of conservation practices. It appears that younger farmers perceive erosion as a problem and conservation practices as being profitable and are, therefore, more willing to accept the associated financial risk.

Denison (1964) postulated that education plays a significant role in productivity regardless of occupation; that is, the more education an individual has, the higher productivity will be. More highly educated people tend to be more favorable toward controlled land use since they can perceive the potential impacts and consequences of uncontrolled use. Also, education is an indicator of the farmer's ability to deal with abstract ideas and should facilitate the operator's capability to determine the feasibility of the alternative solutions being proposed for soil and water problems. The Council for Agricultural Science and Technology (1981) suggested that U.S. farmers on better quality land are also likely to have better education and managerial skills and to participate more actively in local conservation programs and organizations than those on poorer quality land.

TYPE OF FARM OPERATION

Soil conservation measures that can be easily integrated into the existing farm production system are much more likely to be adopted than systems that would require a significant change in the farm operation. For instance, inclusion of forage crops would imply that a grain farmer raise cattle, find a suitable market for the crop, or plow under the crop to enhance the soil. Adding livestock to the farming system would require year-round supervision, something which cash crop farmers might be reluctant to do.

TYPE AND FORM OF INFORMATION

The adoption of soil conservation measures is highly dependent on the type and form of technical and economic information. To make rational decisions on the adoption of conservation practices, farmers need accurate and easily understood information. This includes information such as long and short-run economics of conservation systems, recommended cultural practices and rates of soil erosion for various farming practices.

Although most farmers in southwestern Ontario were aware of soil erosion problems, less than half indicated that they wanted to adopt new or additional soil management practices (Wall, et al, 1985). The most significant reasons for not implementing measures included poor economics, lack of available knowledge and lack of time. The lack of information and, in some instances, misinformation are major reasons for farmers not adopting conservation farming practices. Their perceptions of poor economics of conservation tillage is probably due, in part, to the fact some equate yields to financial returns.

AVAILABILITY OF SOLUTION

The key to preventing soil degradation is the availability of economically viable production alternatives that are non-degrading. Only for some farms are economically and technically feasible solutions currently available. Further research is needed in such areas as pest control, tillage equipment and cultural practices such as fertilizer placement to overcome problems associated with some conservation techniques. Improvements in these areas will require continued research efforts by both the private and public sectors.

Both the federal and provincial governments are making commitments to soil and water conservation research. Agriculture Canada has committed about 3.5% of its $255 million research budget to basic and applied research related to soil and water management (Agriculture Canada, 1985). To achieve the largest possible impact on adoption rates, these expenditures should be directed at projects aimed at reducing or eliminating current economic and technical constraints to soil conservation.

GOVERNMENT PROGRAM INSTRUMENTS

The need for government involvement in soil and water activities is generally accepted by the population as a whole. In the United States, a survey in 1979 found Americans supported federal action to protect farmland from erosion by a seven to one margin (Korshing and Nowak, 1983). In Canada, substantial resources for soil and water conservation programs have recently been committed under federal-provincial agricultural development agreements. Thus far, these agreements have committed about $62 million over a 5-year period with the majority of the funds being used to improve adoption rates. A number of provinces also have their own provincially funded soil and water conservation programs. For example, in Ontario, the Ontario Conservation and Environment Protection Assistance Program will pay 50% of the cost of erosion control measures, to a maximum of $7500 per farm operation.

Governments have a variety of instruments that could be used to increase the adoption of soil conservation measures. These include:

- financial assistance (capital grants, cost sharing, income tax changes, and financial assistance to non-government organizations);
- technical assistance (soil conservation extension personnel and increased information dissemination);
- research;
- demonstrations;
- legislative action (establish conservation districts, cross compliance,[2] and legal penalties); and
- crop insurance.

However, instruments that do not promote voluntary adoption of soil conservation measures will probably be resisted by the farm community. A survey of farmers in Iowa in 1980 found that economic incentives and educational programs were acceptable to the majority. Only 28% indicated economic penalties were acceptable and 24% viewed legal regulations as an acceptable method of controlling erosion (Korshing and Nowak, 1983).

In Canada, only a limited number of program instruments have been used to increase the adoption of soil conservation measures. Technical assistance is available in most provinces although the availability and extent varies considerably. In western Canada, the Prairie Farm Rehabilitation Administration has approximately 30 people working full time on soil conservation and related extension activities. Federal expenditures in the prairies for conservation diagnostic services are approximately $750 000 annually (Agriculture Canada, 1985). Ontario has recently hired a number of soil conservation extension officers but, in general, efforts are inadequate in many regions when compared to the magnitude and cost of soil erosion.

Demonstrations have been used to a limited extent in certain regions, most notably the prairies and Ontario. Fewer than 1% of the farmers in southwestern Ontario who adopted soil conservation measures indicated demonstrations as a source of information (Wall, et al, 1985). In the United States, demonstrations have been used much more extensively.

Other government instruments such as the establishment of conservation districts and financial assistance to non-government organizations have also been used in some provinces. Instruments such as cross compliance, income tax changes and legal penalties could also be used to increase the adoption of soil conservation measures. These instruments, however, must be evaluated against such measures as equity, cost, complexity of administering and difficulty in targetting before being implemented. The complexity of the adoption process dictates that a variety of program instruments be used by governments to increase adoption rates.

CONCLUSION

This article has outlined factors that influence the adoption of soil conservation methods. It is apparent that motivating farmers to adopt soil erosion control practices is a complex and dynamic process.

This process begins with the awareness of the problem among farmers and an understanding by others of the factors influencing adoption. As indicated by the low adoption rates, awareness of the problem does not result in adoption by the majority of farm operators. Adoption of soil conservation measures depends on unique farm characteristics such as physical factors, farmer's personal characteristics, type of farm and the availability of solutions.

Farmers need specific information on both the short- and long-term economics of soil conservation technologies. A lack of information or information that is not easily understood can result in the adoption of inappropriate technologies or the repudiation of appropriate technologies.

Research is needed to develop and improve economically viable soil conservation farming systems. In Canada, research on the relationship between socioeconomic factors and adoption rates, and the selection of appropriate program instruments, would also contribute to higher adoption rates for conservation measures and a better understanding of this process to help ensure the sustainability of Canadian agriculture.

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[2] Cross compliance is an instrument which links government assistance to acceptable conservation practices.

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Modeling the economic returns from fixed and soil moisture-based flexible rotations

J.B. Bole and B.S. Freeze[1]

The predicted yields and economic returns for flexible cropping systems are compared with those of continuous barley and rotations of barley-fallow, calculated from 200 random "years" of available spring moisture and precipitation data at Lethbridge. Basing cropping decisions on available spring moisture can return an average of $14.33/ha per year more than continuous barley and $22.08/ha more than a barley-fallow rotation. Although income variability with flexible rotations is much greater than with a barley-fallow rotation, it is less than with continuous cropping.

INTRODUCTION

Cereal producers on the Canadian prairies face a dilemma in their choice of cropping systems. They are being encouraged to minimize summerfallow to reduce the rate of soil degradation by erosion, salinization and nutrient loss. At the same time, uncertain prices and increasing costs force producers to seek crop rotations that minimize risk. Summerfallowing has been shown to reduce crop failure by providing adequate spring reserves of soil moisture. This analysis was conducted to determine what effect cropping decisions based on soil moisture would have on yield, net return and income.

The direct relationship between available water and crop yield in semiarid regions has long been recognized. Staple and Lehane (1954b) noted that if evapotranspiration was less than 125 mm/year in southern Saskatchewan, no crop was produced but wheat yield increased 10 kg/ha with each additional millimetre of water used.

The complexity of this situation was also recognized by Staple and Lehane. They reported (1954a) that the yield response to available water was curvilinear with higher incremental responses at higher levels of water. Precipitation was shown to be 1.5 times more effective than spring moisture. Read and Cameron (1981) found that in years with less than 100 mm May-July precipitation, 1 mm of available spring moisture increased yields by 9.3 kg/ha whereas in years of higher rainfall, the incremental response was only 2.7 kg/ha.

A producer must evaluate the expected returns over two stubble crops compared with that of a summerfallow crop to decide if land should be recropped or fallowed. The risk of crop failure as well as the average expected return influence the decision. The return depends largely on the final crop price, growing season precipitation and available spring moisture, but only the latter is known at seeding time. Research and extension agronomists have advocated flexible cropping systems wherein spring moisture reserves are used to determine if land should be recropped or fallowed.

A flexible rotation requiring 70 cm of moist soil for recropping was included in a rotation initiated at Agriculture Canada's Lethbridge Research Station in 1951. Guidelines for recropping based on the depth of moist soil and soil texture were developed for southwestern Saskatchewan in 1960 (Janzen, et al, 1960). Brown, et al, (1981) developed such guidelines for Montana and North Dakota that include precipitation probabilities for various regions. Halvorson and Kresge (1982) developed the FLEXCROP computer model to help producers make moisture-based decisions for a range of dryland crops. Goos, et al, (1984) used an interaction chi-square test to define critical levels of available soil water at seeding in North Dakota. We have developed a spreadsheet program for personal computers (RECROP: barley recropping decision model) to let producers assess these factors when making recropping decisions for barley production.

METHOD OF ANALYSIS AND DATA SOURCES

We used the RECROP model, described in the Appendix, to examine the increase in production, expected returns and risk associated with recropping based on fixed and flexible barley rotations. The sensitivity of the break-even level of soil moisture required for recropping to the barley price, nitrogen (N) fertilizer price and machinery operating costs was determined. The expected increase in return from applying nitrogen fertilizer in accordance with measured available spring moisture levels was also evaluated.

Yield relationships

Multiple regression analysis was used to define the barley yield in terms of soil-stored available moisture (as of May 15), growing season precipitation (from May 15 to July 31) and the N-fertilizer level. The data base was a 5-year study conducted on dark brown chernozemic soil (Bole and Pittman, 1980). Spring moisture levels were varied by irrigating in the fall with 2.5, 5, 7.5, or 10 cm of water, not irrigating, or by covering the soil with polyvinyl chloride sheeting to exclude snowmelt and early spring rain. The 12 m $\times$ 12 m main plots were replicated six times with six fertilizer-N levels (0-180 kg/ha) split on each main plot. The following regression equation accurately defined yield as a function of available spring soil water (W_s in mm), growing season precipitation (GSP in mm), and available soil NO_3-N plus fertilizer N (kg/ha):

Barley yield (kg/ha) =

$$-2196 + 40.39\,W_s - 0.1027\,W_s^2 + 10.82\,GSP + 0.4908\,N - 0.0412\,N^2 + 0.0242\,W_sN + 0.0805\,GSP\,N$$

where: $R^2 = 0.81$ and $N = 611$

All coefficients were statistically significant, except that for N, which was retained because of the significant N^2 term. The GSP^2 included in the previous analysis (Bole and Pittman, 1980) was deleted from the regression since it led to the prediction of unreasonably high yields under conditions of low spring moisture and low precipitation.

The RECROP model will only be useful when the yield equation is valid. The present regression yield equation was validated by comparing estimated with actual yields in independent fertility studies conducted in the dark brown and black soil zones of Alberta. Its accuracy outside the scope of the data used in its derivation or in other soil zones is unknown.

Random years

The yields and net returns were studied over 200 random "years" of spring moisture and growing season precipitation. The distribution function of GSP or W_s was determined[2] and the computer was used to generate a random series of 200 values of GSP and W_s fitting the distribution function. These were considered as years.

Yield and return for fixed and flexible rotations

Barley yields and net returns were determined for each year based on scenarios of: continuous barley; a fixed 2-year rotation with one-half of the land cropped to barley and one-half fallowed; a cropping rotation where one-half of the land was summerfallowed when the W_s was less than 79.5 mm (the break-even level for the data in the model) and all the land cropped to barley when W_s exceeded 79.5 mm (50% flexcrop); and a flexible rotation where all the land was fallowed when W_s was less than 79.5 mm (100% flexcrop). Fallowed land was always cropped the following year. All variables were calculated based on the total area (including fallow) assuming that the rate of N applied was optimum for measured spring moisture and average precipitation. Returns were calculated based on average soil test nitrate levels to 60 cm depth of 22 kg/ha in stubble and 75 kg/ha in fallow.

Fertilizer-N rates based on spring moisture

The regression model was used to determine the yields and net returns from applying fertilizer N at rates optimum for average W_s and average GSP versus measured W_s and average GSP. The difference represents an estimate of increased return and decreased variability, which would be expected from basing fertilizer-N rates on actual spring moisture reserves rather than on long-term averages. The optimum N rate was that at which an additional unit of fertilizer N would produce an increase in yield with a value equal to the cost of a unit of fertilizer. The analysis was conducted only for a continuous barley rotation over the 200 random years.

SENSITIVITY OF THE BREAK-EVEN LEVEL OF AVAILABLE SOIL WATER REQUIRED FOR RECROPPING

The available moisture in the soil which would, with average precipitation, provide an equal return from recropping or summerfallowing the land in order to crop it the next growing season was termed the "break-even" level of W_s. The effect of economic factors on the critical W_s level needed for recropping was investigated.

The barley price had a marked effect on the break-even level of W_s; it varied from 72 mm with barley at \$160/t to 90 mm at \$80/t (Figure 1). Nitrogen fertilizer prices and machinery operating costs were shown to have less effect than barley price on critical moisture levels required for recropping. A similar 33% increase or decrease in current fertilizer prices (\$0.66/kg) resulted in a range of necessary water levels of 75-83 mm. The same variation in machinery operating costs only changed the water required by 3.5 mm. Goos, et al, (1984) found that a similar level of stored available moisture at seeding (64-94 mm) was required for equal probability of crop failure or success of recropping under North Dakota conditions.

The expected value of net return at the break-even level of W_s responded in a similar manner, increasing from \$60/ha per year to \$210 for both recropping and summerfallowing systems as the barley price increased from \$80/t to \$160. Increasing the price of fertilizer N from \$0.44/kg to \$0.88 only decreased the net return from \$125/ha to \$119. This lack of sensitivity to N price is due to the model optimizing the N rate based in part on the price of fertilizer N.

BARLEY YIELDS

Average barley yields were higher in a continuous rotation than in a barley-fallow rotation (2.84 vs 1.94 t/ha) since one-half of the land produced no yield in the fallow rotation (Figure 2). Yields of continuous barley were three times as variable as in the barley-fallow rotation. Fallowing land when the available water at seeding was less than 79.5 mm produced average yields nearly as high as those from continuous barley. However, since these rotations had situations where land with inadequate moisture was cropped (maximum 50% fallow), or where the entire area was fallowed, yields were even more variable than with continuous barley.

FIGURE 1 SENSITIVITY OF THE "BREAK EVEN" AMOUNT OF AVAILABLE SOIL WATER REQUIRED FOR RECROPPING (—), AND THE NET RETURN AT THAT AVAILABLE WATER LEVEL (--) TO BARLEY PRICES, NITROGEN FERTILIZER PRICES AND MACHINERY OPERATING COSTS

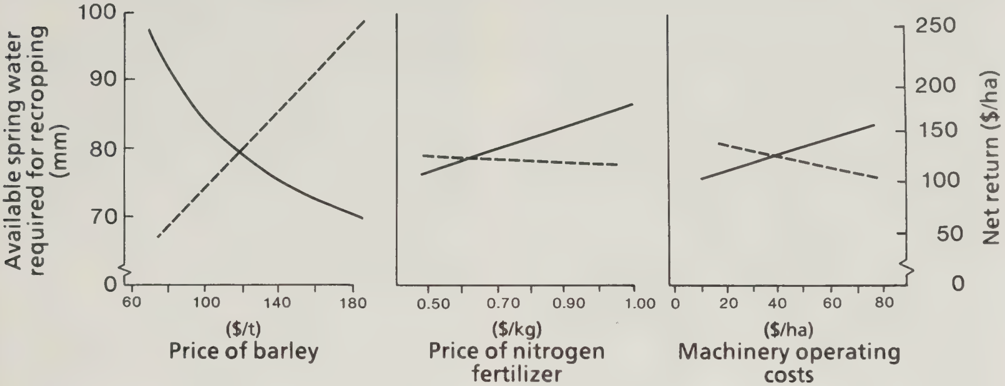
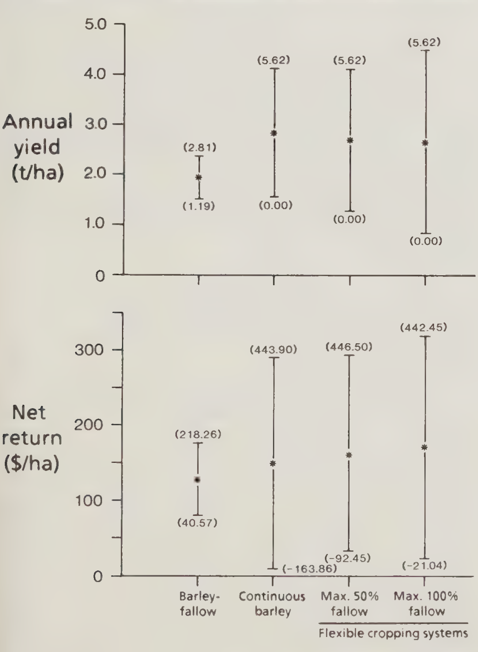


FIGURE 2 MEAN (*) AND STANDARD DEVIATION (|—|) OF THE ANNUAL YIELD AND NET RETURN ON CASH AND LABOR COSTS FOR FIXED AND FLEXIBLE BARLEY-FALLOW CROPPING ROTATIONS. MAXIMUM AND MINIMUM VALUES ARE IN PARENTHESES.



Variability of the actual yields was moderate for the 100% flexible cropping rotation in the 144 of the 200 years in which spring moisture was adequate for recropping. The standard deviation of 0.91 t/ha was approximately double that of the barley-fallow rotation, reflecting the nearly double average yields (3.71 t/ha). The coefficient of variability was thus only slightly higher (25 vs 22%). It should be emphasized that the 100% flexible cropping rotation is included only for comparison because it would be agronomically unsound with conventional tillage, from the standpoint of erosion control, in most of the prairies. It could, however, be considered feasible with a no-till, chemical-fallow system, but the cash costs would be different from those used in this analysis.

It is of interest to note that the barley-fallow rotation would require the annual application of only 14.6 kg/ha of fertilizer N whereas continuous barley would require 69 kg/ha. This documents the increased dependence on the nitrogen fertilizer industry if producers are to maintain their current trend of reducing the proportion of their land in fallow.

This differential return was based on a fixed barley price of \$114.82/t, which was the market price of barley at the time the analysis was conducted (1985). The costs of other inputs are outlined in the Appendix. Higher barley prices would increase the difference in returns among rotations, making fallow-based rotations less attractive. An anticipation of higher barley prices would cause producers to recrop at lower spring moisture reserves and thus completely change the cropping patterns, yields and returns. The model could be used to study the effect of anticipated barley price on returns, but this was not attempted.

NET RETURN

The average net return over cash and labor was increased from $126.63 for the barley-fallow rotation to $149.21 for continuous barley. Flexible cropping rotations with a maximum of 50 and 100% fallow produced average annual returns of $163.54 and $171.29 which were 30 and 35% higher than the fixed 2-year rotation, respectively (Figure 2).

The standard deviation of return for continuous barley was nearly as great as the average return while that of 50% flexcrop rotation was 80% as large. This indicates that some income stability was achieved through fallowing land in years when the spring moisture reserve was less than 80 mm. Although the mean return minus the standard deviation remains positive for all rotations, the minimum income was negative for all rotations except barley-fallow (Figure 2). Less risk was associated with the rotations involving fallow, in that the minimum return was −$163.86/ha for continuous barley and negative in 35 of the 200 random years, while it was only −$91.45/ha and negative in 22 of the 200 years with 50% flexcrop. The 100% flexcrop rotation only produced negative net returns (−$21.04) in the 56 years when the land was fallowed. The barley-fallow rotations did not result in negative returns. The much greater variability of net return from continuous cereal compared with the cereal-fallow rotation was previously documented by Zentner, et al, (1979b).

It should be pointed out that the income does not include any crop insurance payout in years of low return although crop insurance is included in the cash costs. This would reduce the income variability and risk of the intensively cropped rotations. The model also does not include any differential degradation of land more frequently summerfallowed, although agronomists have associated enhanced erosion, salinization and nutrient depletion with this practice (Western Provincial Conference, 1984).

ADJUSTING FERTILIZER-N RATES FOR AVAILABLE SPRING MOISTURE

Since the optimum level of fertilizer N is directly related to the yield and evapotranspiration level of the crop (Greenwood, et al, 1974), agronomists have advocated adjusting fertilizer N to reflect available spring water. De Janvry (1972) developed an economic model that estimated optimal levels of fertilizer based on risk due to weather variability. Talpaz and Taylor (1977) extended that concept by including uncertainty about yield response in their model developed for dryland sorghum in Texas. They concluded that a producer willing to accept a loss in 3 years out of 10 should apply the profit-maximizing rate of N when soil moisture is high, but should apply lower rates when moisture is less favorable.

We used the same 200 random years to compare the expected return from applying N fertilizer in accordance with measured W_s with the return from applying rates optimal for the mean W_s with average and below-average GSP. The relationships in the model suggest fertilizer-N rates should be increased 0.29 kg/ha for each additional millimetre of W_s. When scenarios of applying N based on average and measured W_s were compared for continuous barley, we found little difference in the net return or its variability (see table). The mean return was increased only $1.23/ha. When this comparison was made at an N rate which would have been optimum in drier years with a GSP of 101 mm (P = 0.70), the mean return was increased $2.17 by adjusting N rates for W_s.

While returns of $1-$2/ha can be substantial to a large producer, the delay of fertilizer-N application until immediately prior to seeding and the constraints on labor and machinery at that time may make the practice of adjusting fertilizer rates for spring moisture conditions unfeasible or uneconomic except in years when soil moisture reserves are well above average. In those years additional fertilizer N could be applied at seeding or top-dressed later in the growing season.

THE EFFECT OF ADJUSTING NITROGEN (N) FERTILIZER RATES ON MEASURED VERSUS MEAN AVAILABLE SPRING MOISTURE (W_s) FOR A CONTINUOUS BARLEY ROTATION BASED ON 200 RANDOM YEARS OF W_s AND GROWING SEASON PRECIPITATION (GSP)

	Optimum N for measured W_s			Optimum N for mean W_s		
	N[1] (kg/ha)	Yield (t/ha)	Return ($/ha)	N[1] (kg/ha)	Yield (t/ha)	Return ($/ha)
129 mm GSP (P = 0.50)						
Mean	69.4	2.84	149.21	65.8	2.81	147.98
Standard deviation	14.6	1.29	141.31	—	1.21	139.40
Maximum	111.2	5.62	443.90	65.8	5.20	422.17
Minimum	49.7	0.00	−163.86	65.8	0.00	−174.49
101 mm GSP (P = 0.70)						
Mean	42.0	2.65	145.45	38.5	2.61	143.28
Standard deviation	14.6	1.24	134.63	—	1.13	129.93
Maximum	83.8	5.32	426.75	38.5	4.82	396.51
Minimum	44.3	0.00	−145.79	38.5	0.00	−156.47

[1] Rate of fertilizer N in kg/ha assuming a soil test level of 22 kg/ha of NO_3-N

CONCLUSION

A flexible cropping system whereby land is recropped when spring moisture reserves are adequate and summerfallowed when reserves are inadequate has the potential to increase average net income substantially over a crop-fallow rotation. It can also significantly increase income over a continuous barley rotation and reduce some of the associated risk. The flexible cropping system would have the added benefits of greatly reducing the area summerfallowed and subsequent erosion and nutrient loss, as well as virtually eliminating the movement of excess water below the rooting zone which leads to nutrient leaching and salinization.

While the analysis was conducted for barley because of the presence of suitable validated yield relationships, Zentner, et al, (1979a) have shown very similar returns for barley and spring wheat in the dark brown soil zone. This suggests that differential returns and variability for the fixed and flexible rotations would be similar for production of spring wheat. Adjusting fertilizer-N levels according to the level of available spring moisture increased average returns slightly but the increase might only justify the inconvenience of delaying fertilizer application until seeding time during years when spring moisture reserves are well above average.

A personal computer model is available from the authors to allow producers, agronomists and economists to examine the economics of cropping decisions for specific situations.

APPENDIX

RECROP: barley recropping decision model

The RECROP model has been written for Visicalc or Lotus 1-2-3 software (Apple II or IBM personal computers). It is amenable for use by individual producers or extension specialists for site-specific scenarios. Inputs in the model must be replaced by the measured spring moisture reserves and average growing season precipitation for the area. Average production and fertilizer costs for the producer's situation would be used. The price for barley can also be modified, based on market expectations.

We have developed a spreadsheet program which calculates the expected value or weighted average return for the two alternatives of recropping barley stubble versus summerfallowing and cropping the following year. Factors considered in the model are available spring soil water, soil test level of nitrate-N, cash and labor costs of recropping versus summerfallowing, barley prices, and growing season precipitation. The model uses decision theory procedures (Halter and Dean, 1971) wherein the probability of levels of each variable is used to budget the net returns for each combination of spring moisture, growing season precipitation and crop price. The decision to recrop or summerfallow is then made on the basis of the weighted average of net returns for each alternative.

Default data in the model used for the analysis in this article (and the probability of each level) included:

— growing season precipitation (mm): 70 (0.2), 101 (0.2), 129 (0.2), 162 (0.17), 183 (0.23) — based on 82 years of precipitation data, Lethbridge, Alberta;

— barley price ($/t): $87.26 (0.33), $114.82 (0.34), $142.38 (0.33) — based on prices at the time this article was prepared (early 1985) and the coefficient of variation for grain price used by Zentner, et al, (1979a);

— fertilizer nitrogen: $0.66/kg of N (average southern Alberta price, spring 1985);

— fertilizer phosphorus: $0.59/kg of P_2O_5; and

— cash and labor costs without N fertilizer: crop on stubble, $131.10/ha; crop on fallow, $155.76/ha; fallow, $21.04/ha — based on data provided for 1983 by Alberta Agriculture.

Other assumptions used in the analysis included:

— soil test NO_3-N and fertilizer-N levels are additive (and thus of equal value);

— soil test NO_3-N increases by 53 kg/ha during the summerfallow year. Default soil test NO_3-N levels of 22 and 75 kg/ha were used for stubble land and summerfallow land (based on 12 years of field data at Lethbridge);

— the minimum value of available soil moisture for summerfallow land is 135 mm (18-year mean for two sites in southern Alberta). When stubble land had more than 135 mm, that value was used for summerfallow land as well;

— the economic optimum rate of fertilizer N based on the measured W_s level and mean GSP was applied; and

— the W_s level in any year is independent of the GSP of the previous year.

To compare net returns of recropping stubble versus summerfallow, the net returns from two stubble crops are compared with the returns from a summerfallow-crop rotation. The model accomplishes this comparison using the following relationship:

$$(P_B \times Y_{ST}) - C_{ST} \quad vs \quad \frac{(P_B \times Y_{SM})}{2} - \frac{(C_{SM})}{2} - \frac{(C_{SMC})}{2}$$

where:
P_B = price of barley ($/t)
Y_{ST} = yield of barley on stubble (t/ha)
C_{ST} = costs (cash plus labor) on stubble ($/ha)
Y_{SM} = yield of barley on summerfallow (t/ha)
C_{SM} = costs (cash plus labor) in summerfallow year ($/ha)
C_{SMC} = costs (cash plus labor) in summerfallow crop year ($/ha)

Non-cash costs, except labor, are excluded, as they are fixed in the short term and vary significantly from farm to farm.

The spreadsheet RECROP model documentation is available from the Lethbridge Research Station.

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[2] Precipitation (GSP) from May 15 to July 31 at Lethbridge was described by a log distribution function based on 80 years of precipitation records. The function had a mean ± standard deviation of ALOG (2.112 ± 0.2065). This represents a mean of 129 mm with a range of 80-208 mm. The function was truncated at the lower and upper observed levels of GSP in the yield model (55 and 183 mm). Similarly, W_s was generated based on 17 years of data on spring moisture available in recropped plots to a depth of 120 cm. The W_s function, described by the function ALOG (1.941 ± 0.221) representing a mean of 87 and a range of 52-145 mm, was truncated at 32 and 241 mm.

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The economic impact of extended crop rotations on Saskatchewan grain farms

R.A. Schoney and T. Thorson[1]

INTRODUCTION

Probably the most unique feature of prairie cropping patterns is the inclusion of summerfallow in crop rotations. The 1981 Census reports the ratio of summerfallow to total tillable acreage (SF ratio) as 0.456, 0.413 and 0.303 for the brown, dark brown and black soil zones in Saskatchewan. Generally, western farmers incorporate summerfallow in their rotations to conserve moisture, reduce commercial fertilizer requirements, improve weed and pest control, increase profits and provide income stability (Anderson, 1981, pp. 58-61).

The main reason for summerfallowing in the drier parts of Saskatchewan is to store moisture in the soil. However, it is inefficient because most moisture is conserved during the first winter when crop stubble traps snow and not in the second winter when the fields are bare (University of Saskatchewan, p. 71). The second most important benefit of summerfallowing is the accumulation of nitrogen due to demineralization of organic matter; a summerfallowed field contains approximately twice as much available soil nitrogen as a stubble field (University of Saskatchewan, p. 78).

While research has shown that reduced summerfallow may be profitable, it may also increase risk (Zentner, et al, 1979a, 1979b and 1984; and Smith and Lee, 1981). In addition, summerfallow reduces soil quality through decreased organic matter and increased soil salinity. These effects are not necessarily irreversible but their associated costs can be considerable and possibly prohibitive.

The current cost/price squeeze encourages western grain producers to search for new ways to reduce costs and increase revenues. Fixed costs of producing cereals include machinery and building ownership charges and land costs, that typically account for 60-75% of the total costs (Schoney, 1985). High proportions of summerfallow can result in high average fixed costs due to low utilization of machine, management and land resources, thus there is strong incentive to reduce average total costs per given area by reducing the proportion of fallowed land.

This article reviews two studies that assess the profitability of extending the cropping rotation by increasing the proportion of crops and decreasing that of summerfallow in both the short and longer runs. It is important to distinguish between the two lengths of run because, in the longer run, major changes in farm organization usually accompany the shift to more crops. This may be caused by wheat quotas that lead to the inclusion of less profitable crops in the farm plan, and may include adjustments to machinery size and replacement patterns.

SHORT-RUN ANALYSIS OF CROPPING ROTATIONS

To maximize short-run profits, a cropping rotation that maximizes returns above variable costs should be selected.[2] Where yields and prices are highly variable or uncertain, a convenient management tool is break-even analysis.[3] In the following analysis, it is assumed that the decision maker is maximizing short-run profit, the most uncertain variable is yield and the two alternatives are wheat-fallow and wheat-wheat-fallow rotations. In the short run, the break-even equation is determined by setting the returns above variable cost per unit of land of a 2-year rotation equal to that of a 3-year rotation and solving for yield. The resulting break-even yield is:

$$Y_2 = \frac{Y_1}{2} + \frac{(2\ TVC_2 - TVC_1 - TVC_3)}{2P}$$

where:

Y_n = yield of fallow wheat or stubble wheat
TVC_n = total variable costs
P = price of wheat
1 = wheat on fallow
2 = wheat on stubble
3 = fallow

The following analysis is based on costs presented in Table 1 which are taken from the 1985 Top Management Workshops. Note that costs between the two soil zones are remarkably similar for wheat on fallow, but that there is a difference of $5.66 between the two zones for producing wheat on stubble. This is primarily due to differences in fertilization rates.

TABLE 1 TOTAL VARIABLE COSTS, SHORT-RUN ANALYSIS ($/ac)

	Soil zone	
Enterprise	Brown	Dark-brown
Wheat on fallow	50.68	50.20
Wheat on stubble	57.15	62.81
Fallow	8.37	10.40

Source: Schoney, R.A., *1985 Costs of Producing Crops and Forward Planning Manual for Saskatchewan*

Results

Break-even wheat stubble yields are presented in Tables 2 and 3 for the brown and dark brown soils. On the brown soils using a farmgate wheat price of $3.45, a stubble wheat yield of 21.5 bu/ac is required to generate the same returns above variable cost or break even with a fallow wheat yield of 27 bu/ac. If typical yield differentials are 6 bu/ac, then under current prices, the 2-year rotation is more profitable. However, long-run yields, estimated by the same Top Management participants, were 24.3 and 27.4 bu, respectively, for wheat on stubble and wheat on fallow,[4] indicating that for this sample a 3-year rotation is potentially more profitable.

TABLE 2 ESTIMATED SHORT-RUN, BREAK-EVEN STUBBLE WHEAT YIELDS, BY WHEAT PRICE, BROWN SOILS

Wheat price	Fallow wheat yield (bu/ac)							
($/bu)	21	23	25	27	29	31	33	35
2.95	19.9	20.9	21.9	22.9	23.9	24.9	25.9	26.9
3.45	18.5	19.5	20.5	21.5	22.5	23.5	24.5	25.5
3.95	17.5	18.5	19.5	20.5	21.5	22.5	23.5	24.5
4.45	16.7	17.7	18.7	19.7	20.7	21.7	22.7	23.7
4.95	16.1	17.1	18.1	19.1	20.1	21.1	22.1	23.1
5.45	15.6	16.6	17.6	18.6	19.6	20.6	21.6	22.6
5.95	15.1	16.1	17.1	18.1	19.1	20.1	21.1	22.1
6.45	14.8	15.8	16.8	17.8	18.8	19.8	20.8	21.8

TABLE 3 ESTIMATED SHORT-RUN, BREAK-EVEN STUBBLE WHEAT YIELDS, BY WHEAT PRICE, DARK BROWN SOILS

Wheat price	Fallow wheat yield (bu/ac)							
($/bu)	23	25	27	29	31	33	35	37
2.88	22.8	23.8	24.8	25.8	26.8	27.8	28.8	29.8
3.38	21.1	22.1	23.1	24.1	25.1	26.1	27.1	28.1
3.88	19.9	20.9	21.9	22.9	23.9	24.9	25.9	26.9
4.38	18.9	19.9	20.9	21.9	22.9	23.9	24.9	25.9
4.88	18.2	19.2	20.2	21.2	22.2	23.2	24.2	25.2
5.38	17.5	18.5	19.5	20.5	21.5	22.5	23.5	24.5
5.88	17.0	18.0	19.0	20.0	21.0	22.0	23.0	24.0
6.38	16.6	17.6	18.6	19.6	20.6	21.6	22.6	23.6
6.88	16.2	17.2	18.2	19.2	20.2	21.2	22.2	23.2

On the dark brown soils using a farmgate wheat price of $3.38, a stubble wheat yield of 24.1 bu/ac is required to break even with a fallow wheat yield of 29 bu/ac. Estimated long-run yields for the same participants on the dark brown soils were 24.3 and 29.3 bu, respectively, for wheat on stubble and wheat on fallow, indicating that at likely 1986 prices 2-year and 3-year rotations would generate about the same annual net returns.

LONG-RUN ANALYSIS OF CROPPING ROTATIONS

In a separate study conducted in 1984-85, the analysis of long-run shifts was based on a comparative, dynamic simulation of representative Saskatchewan wheat farms using the Top Management Model.[5] Long-run economic profitability of alternative rotations is assessed by determining the impact of various rotations on the future terminal or ending net worth of the representative grain farms.[6] Since federal and provincial taxes were included in determining cash flows, all changes also reflect true "after-tax" changes in wealth.

Base representative farms that utilize prevailing production practices and conventional rotations were defined for each soil zone. Annual cash flows, crop production, resource use and net worth were simulated over a 15-year period for each representative farm. This constitutes the base scenario. The base rotation and cropping patterns were then altered to more intensive rotations, and the farm cash flows and future net worth re-simulated over the same period. Three sets of alternative assumptions about machine replacement patterns and sizing are employed in evaluating the extended crop rotations:

- the base machine set — the same set of field and harvesting machines is retained but the replacement age is lowered to maintain the same level of total use at replacement;
- re-sized machines — combines and swathers are re-sized to give the same annual use rate as in the base rotation; and
- constant machine investments per crop acre — the base machine lifetimes are retained but machinery investment per crop acre is increased to the same level as for the base farm.

Representative wheat farms

The wheat farms represent typical grain farms commonly found in that soil zone. Three farms are constructed for each soil zone: a base farm; farm A — an intensive spring wheat farm; and farm B — an intensive rotation farm that included some winter wheat. The base farm and the alternative spring wheat rotation are based on the 1984 Top Management participants augmented by Eight Innovative Acres cooperators located in the brown soils. The sample of 45 farms was divided into "intensive" and "extensive" groups based on cropping intensity and their detailed farm plans, crop production coefficients and costs used to develop the following representative farms. Table 4 gives a description of the base and alternative rotations used in the simulation.

TABLE 4 REPRESENTATIVE CROP MIX BY SOIL ZONE AND ROTATION INTENSITY[1]

Soil and farm type	Spring wheat Fallow (ac)	(%)	Spring wheat Stubble (ac)	(%)	Barley on stubble (ac)	(%)	Winter wheat (ac)	(%)	Canola/ Fallow (ac)	(%)	Fallow (ac)	(%)	Total (ac)
Brown													
Base farm	900	50									900	50	1800
Farm A	600	33	600	33							600	33	1800
Farm B	600	33	200	11	200	11	200	11			600	33	1800
Dark brown													
Base farm	560	39	200	14	120	8					560	39	1440
Farm A	360	25	400	28	320	22					360	25	1440
Farm B	200	14	200	14	320	22	200	14	160	11	360	25	1440

[1] Farm A: intensive spring wheat; Farm B: intensive winter wheat
Source: Based on the 1984 Top Management participants

Farmgate prices used in the long-run study are based on the prices for the 5-year period 1979-80 to 1983-84 and adjusted for transportation costs and the mix of grades produced (Table 5). The sensitivity of the results were tested for changes in commodity prices by varying these prices by 10%. Commodity prices were based on the expectations of 1984 and are considerably greater than the current short-run price expectations. However, if long-run commodity prices were to match current short-run expectations, then many farming operations would not be able to survive and there would be major structural shifts.

TABLE 5 ASSUMED BASE LONG-RUN CROP PRICES, BY SOIL ZONE, 1984 ($/bu)

Soil zone	Wheat	Barley	Canola	Winter wheat
Brown	4.95	2.56	—	4.70
Dark brown	4.87	2.56	7.35	4.70

Source: Based on the 1984 Top Management participants

All crop prices, except canola, are assumed to increase by 3% per year over the 15-year simulation period.

Crop yields by soil type are presented in Table 6. In testing the sensitivity of results to errors in stubble yields, all ratios including those of wheat, barley, canola and winter wheat are decreased or increased by a uniform 10%.[7]

TABLE 6 ASSUMED BASE LONG-RUN CROP YIELDS, BY SOIL ZONE (bu/ac)

Soil zone	Spring wheat Fallow	Spring wheat Stubble	Winter wheat	Barley stubble	Canola
Brown	27.0	21.5	27.0	35.0	
Dark brown	29.0	23.0	29.0	45.0	21.0

Source: Based on the 1984 Top Management participants

Results

Long-run farm production, cash flows and net worth are simulated over a 15-year period for each representative farm in each soil zone, and each price, yield and machinery. All the farms within a soil zone start with the same assets, debt and net worth, so only the change in net worth over the period is presented in Table 9. Because yields vary from year to year and from farmer to farmer, break-even stubble-wheat to fallow yield between the base rotation and the alternative rotation are estimated. The break-even stubble to fallow represents that yield which makes the terminal net worth between the two alternatives equal. Because it is impossible to analytically solve for such yields, ordinary least squares regression is used to fit a curvilinear surface and the resulting regression equation is used to estimate the break-even yield point.

DISCUSSION OF RESULTS

Under short-run price expectations, moving from a 2-year to 3-year cropping rotation is unprofitable except under high levels of management. This may result in substantial shifts back to more fallow on both the brown and dark brown soils. This trend may be further enhanced where farmers perceive that they can reduce input costs.

Unless there are dramatic increases in wheat prices, this trend will also persist in the long run; a combination of low spring wheat prices of $4.45 and low yields cause the extended rotations to be unprofitable in the long run on the brown soils. On the dark brown soils, also using the low spring wheat price of $4.38 and a low stubble-to-fallow yield ratio, the two rotations are very close in profitability — the future value of the difference is $21 096 which is about $992/year.[8] However, both farms are in a loss minimization decision mode; there is substantial erosion in

TABLE 7 ESTIMATED BREAK-EVEN STUBBLE WHEAT YIELDS, BY ROTATION AND SOIL ZONE (bu/ac)

Wheat price ($/bu)	Spring wheat		Winter wheat	
	Base machines	Re-sized machines	Base machines	Re-sized machines
Brown soil zone[1]				
4.46	20.8	20.5	19.4	19.7
4.95	19.7	19.4	18.6	18.6
5.45	19.2	18.6	18.1	18.1
Dark brown soil zone[2]				
4.38	20.6	21.5	17.7	18.9
4.87	20.3	20.0	17.7	18.3
5.36	19.4	19.4	17.4	17.4

[1] Based on a fallow yield of 27.0 bu

[2] Based on a fallow yield of 29.0 bu

equity over the 15-year period. As can be expected, increasing long-run machinery investments per crop acre of the extended rotations to match that of the base farm, shifts the comparative advantage towards less extensive rotations under any combination of low or medium price scenarios and low or medium-low stubble-to-fallow yield ratios.

However, under more favorable prices and/or high stubble-to-fallow yield ratios, the results indicate that farmers should consider shifting to more intense crop rotations with somewhat less reliance on summerfallow. Under the base price, yield and machinery set assumptions, a shift to a more intense rotation using spring wheat can generate sizeable increases in net worths — a total of $103 454 and $88 267 for the brown and dark brown soils respectively. While this seems like a great deal of increased net worth, it is considerably less when converted to an annual equivalent. Using an annualization factor of 21.26, this corresponds to $4866 and $4151 per year respectively for the two soil zones.

TABLE 8 ESTIMATED BREAK-EVEN STUBBLE WHEAT YIELDS, BY SOIL ZONE, MACHINERY INVESTMENT PER CROP ACRE HELD CONSTANT (bu/ac)

	Wheat price ($/bu)	Spring wheat	Winter wheat
Brown soil zone[1]			
	4.46	22.1	22.1
	4.95	21.9	21.1
	5.45	21.1	20.3
Dark brown soil zone[2]			
	4.38	22.0	20.9
	4.87	21.8	19.1
	5.36	21.5	18.3

[1] Based on a fallow yield of 27.0 bu

[2] Based on a fallow yield of 29.0 bu

Not surprisingly, since no timeliness penalties were included in the analysis, the results indicate that the best machinery replacement and sizing strategy is to trade more often but maintain current size. However, the profitability between re-sizing the harvest machinery and decreasing their replacement lifetimes are not great.

The greatest long-run potential for generating a shift to a more intense crop rotation occurs when winter wheat is used to extend the rotation. Only a combination of the lowest ratio of stubble to fallow yields (0.72), wheat prices ($4.45) and maintaining the base machinery investment per crop acre, makes it unprofitable to extend the brown soil rotation using winter wheat; on the dark brown soils, extending the rotation is profitable under all yield ratios, price combinations and machinery combinations. Finally, winter wheat offers far more potential for increased farm profitability than increased production of spring wheat.

CONCLUSIONS

Under the current economic climate, extending crop rotations to include more crops is not likely to be profitable except under relatively low differentials between fallow and stubble yields. Moreover, unless there are dramatic increase in future commodity prices, decreased intensity in cropping rotations can be expected to occur. Most farmers will be minimizing losses and may perceive fallow cropping as a way to decrease input costs. However, under high levels of management, the more intensive rotations may still be profitable — farmers should carefully assess their own yield and cropping potentials.

While it is clear that winter wheat can be profitable for many farmers, its impact on machinery sizing and replacement is more difficult to determine. Because winter wheat is harvested before spring wheat, it spreads the harvesting over more weeks, potentially allowing the same harvesting equipment to cover more area. However, seeding may compete for labor and tractor time with spring wheat harvest, so may require further machinery adjustments.

This analysis is based on deterministic yields and prices. However, the fallow versus cropping of stubble land is a dynamic problem, with year to year adjustment. Farmers adjust their cropping decisions as they "bet" on future weather patterns and prices according to their expectations and spring soil moisture. The resulting economic problem is exceedingly complex, requiring simultaneous consideration of not only biological and climatic variables but also of crop insurance, individual risk preferences, crop quotas, and machinery sizing and replacement patterns. Finally, since it is a dynamic problem, current decisions affect future cropping decisions through the amount of fallow and stubble crops available the following year.

TABLE 9 SUMMARY OF ESTIMATED INCREASED NET WORTHS OVER 15 YEARS, BY TYPE OF ROTATION AND SOIL ($)

Price and yield	Conventional rotation	Extended rotations		Difference	
		Spring wheat	Winter wheat	Spring wheat	Winter wheat
Brown soils					
Spring wheat price = $4.45					
Y = 0.72	12 124	–67 698	11 837	–79 822	–287
Y = 0.80	12 124	101 978	149 865	89 854	137 741
Y = 0.88	12 124	212 571	273 020	200 447	260 896
Spring wheat price = $4.95					
Y = 0.72	316 962	204 830	358 284	–12 132	41 322
Y = 0.80	318 995	422 449	463 830	103 454	144 835
Y = 0.88	316 962	546 411	578 492	229 449	261 530
Spring wheat price = $5.45					
Y = 0.72	576 356	584 848	632 134	8 492	55 778
Y = 0.80	576 275	698 921	747 693	122 646	171 418
Y = 0.88	576 356	807 026	844 104	230 670	267 748
Dark brown soils					
Spring wheat price = $4.38					
Y = 0.72	–47 114	–26 018	95 713	21 096	142 827
Y = 0.80	46 365	146 417	251 403	100 052	205 038
Y = 0.88	128 703	306 901	394 036	178 198	265 333
Spring wheat price = $4.87					
Y = 0.72	251 713	297 545	393 431	45 832	141 718
Y = 0.80	347 167	435 434	540 633	88 267	193 466
Y = 0.88	405 029	581 932	692 852	176 903	287 823
Spring wheat price = $5.36					
Y = 0.72	502 949	557 962	658 679	55 013	155 730
Y = 0.80	572 578	716 067	798 094	143 489	225 516
Y = 0.88	646 163	837 129	911 122	190 966	264 959

Y = ratio of wheat on fallow: wheat on stubble

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[2] Since total fixed costs associated with owning machinery and buildings represent costs incurred regardless of the rotation selected, they can be disregarded. However, as the amount of crops seeded and harvested increases, yields may decline due to penalties for non-timeliness.

[3] A break-even analysis is based on solving for the value of an uncertain variable which causes the objective function of one alternative to equal exactly that of a second alternative. In farm management, the objective functions are often profit, cash flows and costs.

[4] The 1985 sample size of the Top Management participants on brown soils is relatively small — between five and eight farms. Since not all farms that had wheat on fallow also had wheat on stubble, caution should be used in interpreting the data. The wheat on stubble data may represent higher management with correspondingly higher yields.

[5] The Top Management Model is a general farm business simulator that generates annual production costs and returns, machinery usage, income taxes paid, net cash flows and net worths over a 15-year period. Detailed farm level data include machine, crop and field inventories, machine replacement cycles, crop production plans, price trends, interest rates, inflation rates, initial resource endowments and financial position specified for each representative farm. Annual farm plans are constructed from detailed crop recipes and rotations specified for each field. The farm plan determines total production and direct operating costs which, in combination with machine replacements and existing debt service, generate the information required to determine federal and provincial income taxes. These data, plus family living withdrawals, are then used to generate annual cash flows. Cash flow deficits are financed according to their underlying causes. Cash surpluses are either used to prematurely repay intermediate debt or are reinvested at a prespecified rate. Of course, liabilities and assets are adjusted each year for changes in debt position and all assets are revalued at their fair market value.

[6] All changes in farm business which affect profitability are translated into either increased liabilities or assets.

[7] Fallow and stubble yield data for each soil zone are extremely difficult to find. The major sources of data were the 1984 Top Management Workshops and a 10-year yield study (1966-76) done by the Saskatchewan Institute of Pedology. The study gave very good yield data for wheat, barley and canola on both fallow and stubble. The FARMLAB "Innovative Acres" program provided good winter wheat yield information. The resulting representative yields are somewhat higher than the provincial averages because the model farms represent a somewhat higher level of management.

[8] Based on an annualization factor of 21.26 which is calculated using an 11% nominal interest, 3% inflation rate and a 35% income tax bracket.

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Long-term on-farm economic effects of cropland erosion in the black soil zone of Alberta

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INTRODUCTION

Cropland erosion in western Canada and its cumulative long-term on-farm effects on crop productivity, net returns and land values under alternative management systems still lack precise quantitative assessments, barring a few subjective estimates (Coote, et al, 1981 and de Jong, et al, 1983). Such economic assessments are crucial to provide the convincing evidence needed by farmers on the benefits of soil conservation so they can direct their investments within their short-term decision horizons. Lack of research and data on the relationship between crop yields and soil characteristics by soil type and depth, and on erodibility by soil types and climatic regions in western Canada, are generally cited as bottlenecks. Nevertheless, cropland erosion has been acknowledged as the issue of greatest concern in soil degradation across Canada (Agricultural Institute of Canada, 1984). The situation in western Canada is reportedly exacerbated by the crop-fallow systems characterized by low water efficiency, coupled with intensive tillage and high fertilizer use to increase production.

This article attempts to measure the on-farm impact of average long-term cropland erosion in the black soil zone of Alberta on crop productivity in terms of net returns and land values over the short- (1 year) and long-term (50 years) planning horizons, for existing and selected alternative conservation-oriented management systems. Inferences are drawn from the results about the economic impact of erosion control measures and the response of farmers in adopting these measures.

The study uses a recently developed Soil Conservation Economics (SOILEC) model (Dumsday, 1982; Eleveld, et al, 1983) designed to simulate long-run physical and financial consequences of soil erosion under alternative production management systems. The model first estimates the long-term average annual soil loss by weight per unit area through water erosion using the Universal Soil Loss Equation (USLE) (Wischmeyer and Smith, 1978). The estimate is then translated into average annual productivity loss given the initial average topsoil depth of horizons A and B, bulk density and the inherent relationship between the topsoil depth and crop yield rates under four erosion phases. Horizon A soil is formed near the surface and enriched with minerals; horizon B is underneath and enriched with organic matter. The four erosion phases include: no erosion where horizons A and B remain intact; medium erosion where only 10 cm of horizon A remain; severe erosion where no horizon A remains; and very severe erosion where neither horizon A nor B remain. The relationship between the erosion phases is linearly interpolated. The yields thus generated are converted into total revenue using a constant price (net of inflation). A constant cost-of-production (net of inflation) is then calculated to obtain a stream of annual net returns for the given planning period. These are then converted to present values, cumulated and converted to annuities (annualized) for uniform comparison of alternative systems. The land value is generated by capitalizing the annual net returns in the end year of the planning period. The model is capable of handling any number of alternative systems, up to a maximum 50-year planning period for any one defined area (farm, region, province). All required data must be specified in master files — one each per defined area.

The model strictly assumes that the soil displaced from one location is relocated in areas unavailable for crop production and, therefore, totally lost to the production system. In its present form, the model is limited by its inability to estimate wind erosion. Also, certain research-based USLE factor values characteristic of the Canadian prairies, such as the snowmelt runoff and summerfallow cropping factors, are presently non-existant and pose data problems. These limitations were overcome by indirectly incorporating predetermined estimates of wind erosion, using recommended procedures to approximate factor values for snowmelt runoff and cropping differences (Wischmeyer, et al, 1976), and applying appropriate proxy values for soil types from bordering areas in Montana.

The chosen study area — the black soil zone of Alberta — is delineated into 18 homogenous map-unit regions, each within four crop regions.

For each map-unit region, physical (climatic, soil characteristics and cropping practices) and economic (yield, costs, prices and discount rate) data were specified as required for the SOILEC and USLE, and a combination of crop rotations, tillage and support practices (contouring, terracing), representing the existing cropping management and alternative conservation management systems, were defined. In defining the alternative conservation management system, the crop rotation remained constant and the choice of the tillage and support practice combination was based on both the potential to minimize soil loss and the ability to sustain adequate net returns as compared to the existing system.[2]

The SOILEC model was operated for each map-unit region. A real discount rate of 7% (prime commercial bank rate of 11% less an inflation rate of 4%) was used to obtain estimates of long-term average soil loss rate, annual net returns and capitalized land value, for the existing and alternative conservation management systems under short- and long-term planning periods.[3]

Wind erosion rates were incorporated indirectly in all map-unit regions using available estimates. However, the analysis of economic consequences of including wind erosion was limited to one specific map-unit region.

The data used in this study fall under 4 categories: map-unit soil classification and area distribution; physical soil characteristics (bulk density, soil depth) including approximate average USLE factor values by map-unit regions; existing and alternative conservation cropping management systems by map-unit regions; and average crop yields, prices, variable costs-of-production, residue and straw production, and crop yield to topsoil depth relationships, by crops and crop rotation/tillage combination for the four main crop regions.

Tables 1 to 4 present soil and cropping pattern information by map-unit regions. Table 1 describes the map-units in terms of soil classification, crop/weather subregions and area distribution. Tables 2 and 3 show the USLE factor values by map-unit regions along with the bulk density and topsoil depth information. The USLE factors include R (rainfall and runoff), K (soil erodibility), SL (slope percentage and length), C (cover management) and P (support practice such as contour or vertical cultivation). Table 4 presents the details on crop rotation, tillage and support practice systems defined under the existing and alternative management systems for the map-unit regions. The estimates of wind erosion as used in the analysis are also provided in Table 4.

TABLE 1 BLACK SOIL ZONE CROPLAND AREA — ALBERTA

No.	Soil order/ great group[1]	Soil subgroup[2]	Dominant (subdominant)	Major soil series name[3]	Crop/weather region	Area (km^2)
1	A3	079	Orthic black	PUR, BZR	Southern	1 494
2	A3	099	Orthic black	PUR, BZR	Southern	880
3	A3	0805	Orthic black	BZE, LET, AID	Southern	5 568
4	A3	080N	Orthic black	BZR, LET, AID	Southern	
5	A3	081	Orthic black (Elluviated black)	HND, BVR, EOR	Red Deer	4 162
6	A3	115S	Orthic black (Elluviated black)	MET, PUY, AID, LTA, BZR, DEL, LET	Red Deer	
7	A3	115N	Orthic black (Elluviated black)	BSK, AID, LTA, ATI, EOR, BLH, FLU, PHS, PED, PCH, AGS, CMO, MGS	Red Deer	35 738
8	A3	115N	Orthic black (Elluviated black)	BSK, AID, LTA, ATI, EOR, BLH, FLU, PHS, PED, PCH, AGS, CMO, MGS	Barrhead	
9	A3	115E	Orthic black (Elluviated black)	EOR, CMO, COA, BVH, AGS, FLU	Vermilion	
10	B2	013	Black solonetz (Black solod)	HER, KLM, CMO, AGS, COA, DUG	Red Deer	
11	B2	013	Black solonetz (Black solod)	HER, KLM, CMO, AGS, COA, DUG	Barrhead	7 026
12	B2	013	Black solonetz (Black solod)	HER, KLM, CMO, AGS, COA, DUG	Vermilion	
13	B2	014	Black solonetz (Grey solod)	COA, MLA	Barrhead	997
14	A3	097	Orthic black (Orthic humic grey soil)	MMO, COA, DUG, CMO	Barrhead	1 634
15	A3	070	Orthic black (Solodic black)	AGS, CMO, POK	Barrhead	3 141
16	A3	082	Orthic black (Elluviated black)	MGS, KVG, FRY, LFN, LCY, HBM	Vermilion	2 872
17	A3	083	Orthic black (Elluviated black)	KLM, EOR, CMO, AGS, WKN	Vermilion	1 585
18	A3	116	Orthic black (Elluviated black)	KLM, EOR, CMO, AGS, WKN	Vermilion	715

[1] A and B represent chernozenic and solenetzic soil order, the suffix 3 and 2 represent great groups black and solonetz.

[2] The subgroups are denoted by three digit numbers comprising dominant and subdominant subgroups as named in the next column. The dominant group accounts for 40% of the area and above; the subdominant group between 20-40%. The variations within the subgroup by agro-climatic factors are indicated by alphabet suffix.

[3] The major soil series name under the subgroups as indicated by three-letter combinations follow the mnemonics used by the Alberta Soil Survey Unit.

Sources: *Soils of Canada*, Vol. 1 and 2
Computerized Land Base — SIDMAP Project
Land Potential Data Base
Alberta Soil Survey Unit, Agriculture Canada

TABLE 2 CROPLAND SOIL PHYSICAL CHARACTERISTICS — BLACK SOIL ZONE, ALBERTA

Crop region	Map-unit[1]	Runoff (R) factor[2]	Topsoil depth[3] Horizon A	Topsoil depth[3] Horizon B	Bulk density[4] (g/cm^3) Horizon A	Bulk density[4] (g/cm^3) Horizon B	Slope[5] (%)	Slope length[6] (m)	Soil erodibility "K" factors[7]
Southern									
	A3079	51	39	33	1.35	1.44	10	92	0.28
	A3099	51	39	33	1.35	1.44	4	92	0.25
	A3080S	51	39	33	1.30	1.43	5	55	0.32
	A3080N	51	39	33	1.30	1.43	5	55	0.32
Red Deer	A3081	61	40	35	1.27	1.40	12	92	0.26
	A3115S	51	39	37	1.30	1.44	4	31	0.26
	A3115N	61	45	42	1.26	1.46	1	37	0.29
	B2013	61	43	43	1.24	1.53	4	55	0.34
Barrhead	A3115N	71	45	42	1.26	1.46	1	37	0.29
	B2014	61	50	45	1.34	1.55	6	92	0.34
	B2097	61	47	46	1.23	1.50	5	92	0.38
	A3070	61	51	43	1.25	1.52	4	92	0.29
	B2013	61	43	43	1.24	1.53	4	55	0.32
Vermilion	B2013	61	43	43	1.24	1.53	4	55	0.32
	A3082	61	43	45	1.28	1.53	6	55	0.24
	A3083	61	44	42	1.25	1.52	6	28	0.36
	A3115E	61	45	42	1.26	1.46	6	52	0.30
	A3116	61	44	42	1.25	1.52	5	42	0.36

[1] Map-unit is defined as a combination of soil order/great group/soil subgroup, as shown in Table 1, columns 2 and 3.
[2] As developed by Tajek, et al, using modified McCool formula
[3] A and B are the two mineral horizons of the topsoil, A formed near the surface, and B underneath the surface enriched with organic matter. The depths of topsoil by map-unit regions are arithmetic averages of the depths of the major soil series in the map-unit regions as shown in Table 1, column 6.
[4] Bulk density is the weight of unit volume of dry soil expressed in g/cm^3. The figures for the map-units are the averages of the soil series within them.
[5] Slope represents the average topography of the map-units. Higher slopes mean more runoff.
[6] Slope length represents distance from the point of origin of overland flow to the point where the slope decreases enough to result in deposition. The longer the slope, the lower the runoff.
[7] As estimated by Tajek, et al

Sources: *Soils of Canada*, Vol. 1 and 2
Computerized Land Base — SIDMAP Project
Land Potential Data Base
Alberta Soil Survey Unit, Agriculture Canada

TABLE 3 COVER MANAGEMENT FACTORS ("C" FACTORS)

Crop region and map-unit	Crop rotation[1]	Tillage system[1]	'C' factors Residue (kg/ha) 560	1120	1680	2240	2240
Southern							
A3079	CSW, CSB	FCL	0.33	0.33	0.33	0.33	0.33
		TPT	0.31	0.31	0.31	0.31	0.31
A3099	CSW, CSB	FCL	0.34	0.34	0.34	0.34	0.34
A3080S		TPT	0.32	0.32	0.32	0.32	0.32
A3080N							
	CFO	FCL	0.08	0.08	0.08	0.08	0.08
		TPT	0.06	0.06	0.06	0.06	0.06
	CSW, CSB	FCL	0.34	0.34	0.34	0.34	0.34
Red Deer							
		TPT	0.32	0.32	0.32	0.32	0.32
A3081	FWW, FCB	FCL	0.39	0.24	0.14	0.08	0.08
		TPT	0.37	0.23	0.13	0.08	0.08
	CFO	FCL	0.08	0.08	0.08	0.08	0.08
		TPT	0.06	0.06	0.06	0.06	0.06
A3115S	FWW, FCB	FCL	0.42	0.28	0.17	0.12	0.12
A3115N		TPT	0.40	0.25	0.15	0.09	0.09
	CFO	FCL	0.08	0.08	0.08	0.08	0.08
		TPT	0.06	0.06	0.06	0.06	0.06
B2013	FWW, FCB	FCL	0.39	0.24	0.14	0.08	0.08
		TPT	0.37	0.23	0.13	0.08	0.08

- Cont'd -

TABLE 3 COVER MANAGEMENT FACTORS ("C" FACTORS) (concluded)

Crop region and map-unit	Crop rotation[1]	Tillage system[1]	'C' factors Residue (kg/ha)				
			560	1120	1680	2240	2240
Barrhead							
A3115	CSW, CSB	FCL	0.33	0.33	0.33	0.33	0.33
		TPT	0.31	0.31	0.31	0.31	0.31
	CFO	FCL	0.08	0.08	0.08	0.08	0.08
		TPT	0.06	0.06	0.06	0.06	0.06
B2014	CSB	FCL	0.33	0.33	0.33	0.33	0.33
A3097		TPT	0.31	0.31	0.31	0.31	0.31
A3070							
	WSF	FCL	0.11	0.11	0.11	0.11	0.11
		TPT	0.11	0.11	0.11	0.11	0.11
	SOF	FCL	0.39	0.29	0.17	0.09	0.09
		TPT	0.37	0.22	0.13	0.08	0.08
	CFO	FCL	0.08	0.08	0.08	0.08	0.08
		TPT	0.06	0.06	0.06	0.06	0.06
	SGF	FCL	0.47	0.29	0.17	0.09	0.09
		TPT	0.32	0.19	0.15	0.07	0.01
Vermilion							
B2013	CSB	FCL	0.33	0.33	0.33	0.33	0.33
A3115		TPT	0.31	0.31	0.31	0.31	0.31
	WSF	FCL	0.11	0.11	0.11	0.11	0.11
		TPT	0.11	0.11	0.11	0.11	0.11
	SOF	FCL	0.37	0.29	0.17	0.09	0.09
		TPT	0.32	0.24	0.12	0.04	0.04
	CFO	FCL	0.08	0.08	0.08	0.08	0.08
		TPT	0.06	0.06	0.06	0.06	0.06
	SGF	FCL	0.37	0.29	0.17	0.09	0.09
		TPT	0.35	0.27	0.13	0.08	0.08
A3082	CSB						
A3083	WSF	FCL	0.11	0.11	0.11	0.11	0.11
		TPT	0.11	0.11	0.11	0.11	0.11
A3116	CFO						
A3115	SGF						
	SOF	FCL	0.37	0.29	0.17	0.09	0.09
		TPT	0.35	0.27	0.15	0.07	0.07

[1] See Table 4 for explanation of crop rotations and tillage systems.

Sources: SIDMAP Project
Montana Soil Conservation Service, Technical Guide

Tables 5 through 9 deal with economic information pertaining to the major crop regions. Tables 5 and 6 show average crop yields by erosion phases. The yields presented in Table 6 were linearly interpolated based on the estimated effects of erosion on yields for wheat, barley and canola as reported for dark brown-black chernozemic soil in Table 5, the base yields for these crops as obtained from Alberta crop enterprise analysis reports, and the average soil depth information pertaining to the map-unit regions from Table 2. Tables 7 to 9 show average residue production levels, crop prices and variable costs-of-production by crops/crop rotations, tillage systems and by crop regions.

It should be noted that all data represented in the tables are approximations of average values for the map-unit regions/crop regions, compiled from various sources as indicated and/or derived using special adjustment procedures, and proxies. For further details, refer to the author's working paper.

RESULTS

The results of the analyses by map-unit regions aggregated to crop regions and black soil zone are given in Table 10. It shows the rates of water erosion, total soil loss, annualized net returns and the capitalized land values for the short- and long-term planning horizons under the existing and alternative management systems. Area proportions were used as weights in aggregating the map-unit results to the crop regions and the black soil zone as a whole.

Average annual soil loss

The annual soil loss rates under the existing system range between 2 and 5 t/ha in most of the map-unit regions, though a few have up to three times this rate. On the whole, however, the erosion rates seem to be moderate and within tolerable limits.[4] The extreme erosion rates in a few map-unit regions can be attributed to diverse topographic and

TABLE 4 CROP ROTATIONS, TILLAGE AND SUPPORT PRACTICES, AND WIND EROSION ESTIMATES BY MAP-UNIT REGION — BLACK SOIL ZONE, ALBERTA

Map-Unit	Crop region	Crop rotations[1]	Tillage systems[2]		Support practice[3]		Wind erosion estimate[4] (t/ha)
			Base (existing)	Alternative (conservation)	Base (existing)	Alternative (conservation)	
A3079	Southern	CSW, CSB	FCL	TPT, NT	VER	CTR	6.00
A3099	Southern	CSW, CSB, CFO	FCL	TPT, NT	VER	CTR	6.00
A3080S	Southern	CSW, CSB	FCL	TPT, NT	VER	CTR	6.00
A3080N	Southern	CSW, CSB, CFO	FCL	TPT, NT	VER	CTR	6.00
A3081	Red Deer	FWW, FCB, CFO	FCL	TPT, NT	VER	CTR	4.50
A3115S	Red Deer	FWW, FCB	FCL	TPT, NT	VER	CTR	4.50
A3115N	Red Deer	FWW, FCB, CFO	FCL	TPT, NT	VER	CTR	4.50
B2013	Red Deer	FWW, FCB	FCL	TPT, NT	VER	CTR	4.50
A3115N	Barrhead	CSW, CSB, CFO	FCL	TPT, NT	VER	CTR	3.00
B2014	Barrhead	CSB, WSF, SOF, CFO	FCL	TPT, NT	VER	CTR	3.00
A3097	Barrhead	CSB, SOF, CFO	FCL	TPT, NT	VER	CTR	3.00
A3070	Barrhead	CSB, SOF, WSF, CFO	FCL	TPT, NT	VER	CTR	3.00
B2013	Barrhead	CSB, SGF, CFO, WSF	FCL	TPT, NT	VER	CTR	3.00
B2013	Vermilion	CSB, WSF, SOF, CFO	FCL	TPT, NT	VER	CTR	1.50
A3082	Vermilion	SGF, CFO, CSB, SOF	FCL	TPT, NT	VER	CTR	1.50
A3083	Vermilion	SGF, SOF, CFO, CSB	FCL	TPT, NT	VER	CTR	1.50
A3115E	Vermilion	SGF, SOF, CFO, CSB	FCL	TPT, NT	VER	CTR	1.50
A3116	Vermilion	SGF, SOF, CFO, CSB	FCL	TPT, NT	VER	CTR	1.50

[1] CSW = continuous spring wheat; CSB = continuous spring barley; CFO = tame hay; FWW = fallow/spring wheat/spring wheat (3 years); FCB = fallow/canola/barley (3 years); WSF = winter wheat/fallow; SOF = fallow/canola (2 years); SGF = spring wheat/fallow (2 years) A combination of these rotations based on distribution of area by crops in the rotation as observed historically (1981 Census) in the map-unit regions is used to represent the respective map-unit regions.

[2] FCL = cultivate in fall and seed in spring (conventional); TPT = till-planting system (minimum tillage); NT = no tillage (zero-tillage)

[3] VER = vertical cultivation; CTR = contour cultivation

[4] Estimate per D.R. Coote

Source: Based on 1981 Agriculture Census, spatially matched (Dumanski, et al)

soil-erodibility conditions specific to those regions. It should also be noted that in area, such map-unit regions are not widespread. The annual average soil loss for the existing system are 5.48 t/ha in the Red Deer crop region, 5.11 t/ha in the Southern crop region, 4.22 t/ha in the Vermilion crop region, and 2.96 t/ha in the Barrhead crop region. The overall average for the black soil zone is 4.43 t/ha of soil loss.

With the conservation management system, the soil loss rates decline in all cases. The decline ranges from 10-50% over the existing system levels, depending on the tillage/support practice combination. By crop regions, an average 15-25% reduction in annual soil loss rate is noticed. Overall for the black soil zone, the soil loss rate decreases from 4.43 t/ha to 3.47 t/ha, a decline of 22%.

In total, the whole black soil zone is estimated to lose an average of 31 million tonnes of topsoil annually under the existing production system. The largest loss occurs in the Red Deer crop region (nearly 50%) because it is the largest area and has the highest erosion rate. With the conservation management system, total soil loss is reduced to 26 million tonnes, a decrease of 16%.

Net returns

On-farm productivity consequences of cropland erosion were evaluated by comparing the annualized present-value net returns under the two planning periods and management systems.

TABLE 5 ESTIMATED EFFECTS OF EROSION ON YIELDS IN FOUR SOIL ZONES (RELATIVE PRODUCTIVITY — %)

Crop	Topsoil eroded: 100% loss[1]	50% loss[1]	Not eroded
Brown chernozemic			
Wheat	50	80	100
Barley	50	80	100
Dark brown-black chernozemic			
Wheat	70	90	100
Barley	70	90	100
Canola	50	80	100
Gray and dark gray luvisol			
Wheat	40	70	100
Barley	40	70	100
Canola	20	50	100
Solonetzic			
Wheat	10	40	100
Barley	10	40	100
Canola	0	30	100

[1] Estimates of historic erosion are expressed as unit areas of land with total topsoil removal. Lands with partial topsoil removal were weighted (on an equivalent yield reduction basis) and proxied as unit areas of total removal.

Source: Marv Anderson and Associates Ltd.

TABLE 6 AVERAGE YIELDS BY EROSION PHASES[1] — MAJOR CROP REGIONS, BLACK SOIL ZONE, ALBERTA

Crop region	Crops specified	Yields by erosion phases (t/ha)			
		Phase 1[2]	Phase 2[3]	Phase 3[3]	Phase 4[3]
Southern	Wheat on stubble	2.01	1.99	1.85	1.59
	Barley on stubble	2.34	2.31	2.17	1.47
	Tame hay	1.07	1.07	1.00	1.00
Red Deer	Wheat on fallow	3.35	3.30	3.13	2.11
	Wheat on stubble	2.82	2.77	2.61	1.78
	Barley on stubble	3.17	3.12	3.00	1.99
	Canola on fallow	1.20	1.17	1.03	1.07
	Tame hay	2.11	2.05	1.98	1.58
Barrhead	Wheat on fallow	2.92	2.85	2.71	1.84
	Winter wheat on stubble	2.92	2.85	2.71	1.84
	Barley on stubble	2.41	2.35	2.23	1.52
	Canola on fallow	0.84	0.80	0.73	0.48
	Tame hay	2.11	2.05	1.98	1.58
Vermilion	Winter wheat on stubble	2.70	2.63	2.48	1.70
	Barley on stubble	2.14	2.09	1.98	1.35
	Canola on fallow	1.20	1.14	1.04	0.68
	Wheat on fallow	2.70	2.63	2.48	1.70
	Tame hay	1.46	1.40	1.32	0.90

[1] See text for description of erosion phases.
[2] Adapted from Consensus of Costs and Returns Reports, Crop Enterprise Analysis Reports, and the Alberta Regional Farm Enterprise Research Project, Alberta Agriculture
[3] As developed based on relationships in Table 4

TABLE 7 RESIDUE PRODUCTION, YIELD REDUCTION AND RESIDUE — BLACK SOIL ZONE, ALBERTA

	Residue production[1] (t/t of yield)	Yield reduction[2]			Residue[3]		
		Fall cultivation	Till/plant (%)	No till	Fall cultivation	Till/plant (%)	No till
Wheat on fallow	1.25	0.0	0.0	–5.3	0	40	65
Wheat on stubble	1.25	0.0	0.0	–5.3	0	40	65
Barley on fallow	1.00	0.0	0.0	–5.3	0	40	65
Barley on stubble	1.00	0.0	0.0	–5.3	0	40	65
Winter wheat on stubble	1.25	0.0	0.0	–5.3	0	40	65
Canola on fallow	1.00	0.0	0.0	–5.3	0	40	65
Canola on stubble	1.50	0.0	0.0	–5.3	0	40	65
Tame hay	1.25	0.0	0.0	–5.3	0	40	65

[1] Based on crop to residue relationships (Canadian ResourceCon Ltd.)
[2] Based on U.S. data as used in SOILEC master file for Illinois farm
[3] Based on U.S. data as used in SOILEC master file for Illinois farm

TABLE 8 AVERAGE CROP PRICES BY CROP REGIONS ($/t)

Crop	Region			
	Southern	Red Deer	Barrhead	Vermilion
Spring wheat	174.52	153.57	160.92	169.00
Winter wheat	146.96	156.14	156.14	156.14
Barley	133.20	114.83	122.63	135.50
Canola	385.78	411.35	458.55	388.00
Tame hay	79.99	71.00	71.00	72.00

Source: *Agriculture Statistics Year Book*, Alberta Agriculture

The short-term planning period results show that the annualized net returns under the existing system vary from $58.61/ha (highest) in the map-unit region A3081 to $31.50/ha (lowest) in the map-unit region A3097. Aggregated for the crop regions, these short-term annualized net returns stabilize to a much narrower range of $44-49/ha. The overall average for the black soil zone is $46.48/ha.

Under the alternative conservation system, the short-term annualized net returns decline in all cases by $3-8/ha, depending on the combination of tillage and support practice. These reductions stem primarily from corresponding yield/cost squeezes consequent to the tillage/support practice combination of the conservation system. Thus, the

TABLE 9 COST-OF-PRODUCTION AND STRAW VALUE PER HECTARE BY CROP REGIONS

Crop region	Crop rotation/tillage combination[3]	Variable cost-of-production ($/ha)[1]	Value of straw ($/ha)[2]
Southern	CSW/FCL	329.35	49.42
	CSB/FCL	313.68	37.07
	CFO/FCL	180.30	—
	CSW/TPT	399.15	37.06
	CSB/TPT	313.66	32.12
	CFO/TPT	180.30	—
Red Deer	FWW/FCL	278.74	42.08
	FCB/FCL	279.97	19.77
	CFO/FCL	258.84	—
	FWW/TPT	275.52	24.71
	FCB/TPT	277.75	9.88
	CFO/TPT	258.84	—
Barrhead	CSW/FCL	358.65	61.77
	CSB/FCL	326.20	37.07
	WSF/FCL	291.88	12.36
	SGF/FCL	187.33	29.65
	SOF/FCL	212.76	—
	CFO/FCL	258.84	—
	CSW/TPT	355.83	44.47
	CSB/TPT	323.71	32.12
	WSF/TPT	289.56	—
	SGF/TPT	185.33	17.29
	SOF/TPT	207.57	—
	CFO/TPT	258.84	—
Vermilion	CSB/FCL	319.85	37.06
	WSF/FCL	291.89	12.36
	SGF/FCL	191.51	29.65
	SOF/FCL	182.14	—
	CFO/FCL	247.18	—
	CSB/TPT	312.85	32.12
	WSF/TPT	282.42	—
	SGF/TPT	187.81	17.30
	SOF/TPT	177.92	—
	CFO/TPT	247.18	—

[1] Vertical cultivation is assumed here. For contouring, an additional cost of $7.41/ha is assumed.
[2] Value of straw is deducted from the variable cost within the model.
[3] See Table 4 for explanation.
Source: Cost and returns reports, Alberta Agriculture (see Table 6)

short-term comparisons show that the existing system realizes a much higher annualized net return than the conservation system in the black soil zone. It is quite apparent, therefore, that incentives for adopting soil erosion control are negative in the short-term.

The evaluation over long-term planning periods, however, substantially alters this picture. Over the 50-year planning horizon, and with similar water erosion rates, the annualized present-value net returns per hectare under the alternative conservation system diminish at relatively slower rates, towards closing the gap with the existing system. This phenomenon is very evident from the generally higher A/E ratios (ratios of annualized net returns between existing and conservation systems, also shown in Table 10) for 50-year planning periods. For example, in the Southern region, the A/E ratios are 84.46% under the 1-year planning period and 85.98% under the 50-year planning period, underscoring the long-term mitigating effects of soil conservation. For the black soil zone as a whole, the A/E ratios differ only marginally (0.4%), however, the direction of change is significant. In general, the magnitudes of A/E ratio differences appear small — perhaps attributable to low water erosion rates.

Land values

Capitalized land values also express the same general relationship as seen with the annualized present-value net returns. However, the differences in absolute terms in land values between the 1-year and the 50-year planning periods and between the two management systems are much larger. On the other hand, the differences in terms of ratio remain closely similar to that of the annualized present-value net returns analysis.

Under the existing management system, the land values for the 1-year planning period range from $630-694/ha by crop regions, with an average value of $664/ha for the black soil zone as a whole. Under the conservation system, the land values decline; the decrease stemming from the reduced current annual returns at the end of the planning period. In the short-term, the largest decline is seen in the Red Deer crop region ($110/ha), and the smallest ($47/ha) in the Barrhead crop region. Overall, the land value for the black soil zone under the conservation system declines to $588/ha from $664/ha under the existing management system. With longer planning horizons, the rates of decline under the conservation management system are relatively slower and level off sooner, underscoring once again the changing perspective under long-term evaluation.

Inclusion of wind erosion

In this analysis, estimated wind erosion rates (Table 4) were added to water erosion rates and the simulations performed for the map-unit region A3079.[5] The results, as shown in Tables 11 and 12, clearly indicate that the erosional consequences are exacerbated. The average annual soil loss rates nearly double, as does the total annual loss. The annualized net returns and land values decline faster, and the gaps in them between the systems narrow quicker, as the planning horizon changes from 1 to 50 years.

Yield/cost effectiveness of conservation tillage

Innovations in tillage technology are rapidly transforming the economics of conservation management systems, mainly in terms of mitigating the yield/cost disadvantages. Table 13 shows the impact on annualized present-value net returns under the assumption of equalized variable costs with the existing system. It can be seen clearly that the annualized present-value net returns under the conservation system exceed those under the existing system for 50-year planning horizon, strongly underscoring the maintenance of productivity with soil conservation.

TABLE 10 ANALYSES RESULTS

Crop region and map-unit[1]	Tillage support practice[2]	Annual soil loss rate by water erosion ($/ha)	Area ('00 ha)	Annual total soil loss (mil. t)	Annualized present-value net returns ($/ha)		Capitalized land values ($/ha)	
					1 year	50 years	1 year	50 years
Southern								
A3079			1 494					
A	FCL/VER	10.50		1.57	46.88	46.26	667	586
B	TPT/VER	9.87		1.48	39.51	39.00	563	519
A3099			880					
A	FCL/VER	2.08		0.18	39.56	38.40	566	539
B	TPT/VER	1.89		0.17	35.09	33.95	501	479
A3080			5 568					
A	FCL/VER	4.15		2.31	46.06	44.67	657	639
B	FCL/CTR	2.60		1.44	38.67	38.57	553	545
Overall[3]			T = 7 942					
A		AV = 5.11		T = 4.06	AV = 45.45	44.30	AV = 648	617
B		AV = 3.89		T = 3.09	AV = 38.39	38.09	AV = 549	532
A/E ratio[4]					84.46	85.98	84.71	86.2
Red Deer								
A3081			4 162					
A	FCL/VER	15.33		6.38	58.61	56.86	383	697
B	TPT/VER	14.43		6.01	49.52	47.84	707	588
A3115			17 869					
A	FCL/VER	2.99		7.40	44.41	43.94	635	601
B	FCL/CTR	1.49		6.04	37.02	36.76	529	508
B2013			703					
A	FCL/VER	10.34		0.24	44.41	44.13	635	613
B	FCL/CTR	6.21		0.12	37.02	36.86	529	512
Overall[3]			T = 22 734					
A		AV = 5.48		T = 14.02	AV = 47.01	46.31	AV = 672	618
B		AV = 4.00		T = 12.17	AV = 39.31	38.79	AV = 562	523
A/E ratio[4]					83.62	83.76	83.6	84.6
Barrhead								
A3115			8 935					
A	FCL/VER	2.32		2.07	48.63	48.38	694	684
B	TPT/VER	2.02		1.80	45.76	45.61	655	645
B2013			3 162					
A	FCL/VER	2.69		0.85	52.61	52.46	751	727
B	FCL/CTR	1.35		0.43	45.96	45.96	654	654
B2014			997					
A	FCL/VER	7.76		0.80	46.06	45.72	657	638
B	TPT/VER	7.34		0.73	43.74	43.49	625	610
A3097			1 634					
A	FCL/VER	4.95		0.81	31.80	31.51	455	447
B	TPT/VER	4.56		0.75	30.20	30.07	432	430
A3070			3 141					
A	FCL/VER	2.44		0.77	53.92	53.70	771	764
B	TPT/VER	2.24		0.70	51.45	51.34	734	729
Overall[3]			T = 17 869					
A		AV = 2.96		T = 5.30	AV = 48.59	48.38	AV = 694	686
B		AV = 2.47		T = 4.41	AV = 45.27	45.16	AV = 647	640
A/E ratio[4]					93.16	93.34	93.2	98.3

Cont'd

TABLE 10 ANALYSES RESULTS (concluded)

Crop region and map-unit[1]	Tillage support practice[2]	Annual soil loss rate by water erosion ($/ha)	Area ('00 ha)	Annual total soil loss (mil. t)	Annualized present-value net returns ($/ha)		Capitalized land values ($/ha)	
					1 year	50 years	1 year	50 years
Vermilion								
A3115			8 935					
A	FCL/VER	4.74		4.24	42.90	42.63	613	603
B	TPT/VER	4.40		3.93	39.17	38.92	561	551
B2013			3 162					
A	FCL/VER	2.38		0.75	52.11	51.89	744	734
B	TPT/VER	2.24		0.71	50.98	50.81	729	722
A3082			2 872					
A	FCL/VER	3.96		1.14	45.62	45.37	653	640
B	TPT/VER	3.46		0.99	43.07	43.74	615	603
A3116			2 300					
A3083								
A	FCL/VER	5.07		1.17	35.66	35.31	509	499
B	FCL/CTR	2.54		0.58	28.24	28.62	403	398
Overall[3]			T = 17 269					
A		AV = 4.22		T = 7.30	AV = 44.08	43.81	AV = 630	619
B		AV = 3.61		T = 6.21	AV = 40.54	40.46	AV = 578	571
A/E ratio[4]					91.97	92.35	91.71	92.2
Black Soil Zone[3]			T = 65 812					
A		AV = 4.43		T = 30.68	AV = 46.48	45.98	AV = 664	637
B		AV = 3.47		T = 25.88	AV = 41.12	40.86	AV = 588	568
A/E ratio[4]					88.47	88.86	88.6	89.2

[1] A = existing system; B = conservation system
[2] TPT = till/plant; FCL = fall cultivation; VER = vertical cultivation; CTR = contour cultivation
[3] T = total; AV = average
[4] A/E ratio = ratio of annualized present-value net returns and/or land values, between existing and conservation systems

TABLE 11 WIND AND WATER EROSION BY CROP REGION

Region[1]	Average annual soil loss rate (t/ha)			Estimate of total soil loss (mil. t)		
	Water	Wind	Both	Water	Wind	Both
Southern						
A	5.11	6.00	11.11	4.06	4.77	8.83
B	3.89	6.00	9.89	3.09	4.77	7.82
Red Deer						
A	5.48	4.50	9.98	14.02	10.23	24.25
B	4.00	4.50	8.50	12.17	10.23	22.40
Barrhead						
A	2.96	3.00	5.96	5.30	5.36	10.66
B	2.47	3.00	5.47	4.41	5.36	9.77
Vermilion						
A	4.22	1.50	5.72	7.30	2.59	9.89
B	3.61	1.50	5.10	6.21	2.59	8.80
Black Soil Zone						
A	4.43	3.50	7.93	30.68	22.59	53.27
B	3.47	3.50	6.97	25.08	22.59	48.47

[1] A = existing system; B = conservation system

CONCLUSIONS

The conclusions relate directly to the black soil zone, although a few broad generalizations are also noted.

The average annual loss of topsoil due to water erosion under the existing system of cropland management in the majority of the black soil zone regions varies from 3-5 t/ha. Adding the wind erosion component nearly doubles the average erosion rate under the existing management system. In all, 54 million tonnes of topsoil loss is estimated annually — 31 million tonnes through water erosion and 23 million tonnes through wind erosion. With the conservation management system chosen in this study, the annual water erosion rates decrease by about 1 t/ha on the average, and by 5 million tonnes in the black soil zone. Although the water erosion rates can be further reduced, the costs of such a system would drive the annual net returns to very low levels.

Isolating the impact of water and wind erosion, under non-inflationary conditions, the study found that under the short-term planning horizon, the existing management

TABLE 12 IMPACT OF INCLUDING WIND EROSION, MAP-UNIT A3079, SOUTHERN CROP REGION

	Average annual soil loss rate by wind and water erosion (t/ha)	Annualized present-value net returns ($/ha)		Capitalized land values ($/ha)	
		1 year	50 years	1 year	50 years
Existing system	16.50	46.88	44.03	667	580
Conservation system	15.87	39.51	37.16	563	495
A/E ratio		84.28	84.41	84.4	85.3

TABLE 13 ANALYSIS REFLECTING NO-COST DIFFERENTIALS, MAP-UNIT A3079, SOUTHERN CROP REGION

	Tillage/ support practice[1]	Annualized present-value of net returns ($/ha)	
		1 year	50 years
Existing system	FCL/VER	46.88	46.25
Conservation system	TPT/VER	46.88	46.33

[1] FCL = fall cultivation; VER = vertical cultivation; TPT = till/plant

system obtained $5.36/ha more of annualized present-value net returns and $50/ha more of land value than the conservation-oriented system, primarily due to higher variable costs associated with the conservation system.

Over the long-term, the conservation management system, by virtue of its lower topsoil erosion rates and productivity mitigating impact, narrows its gap in annualized net returns and land values with the conventional system. This effect is better pronounced when the differences in erosion rates are higher. The magnitude of this effect is basically dependent on the depth of topsoil and the yield response (decrease) to topsoil depletion through erosion. In the black soil zone, the reasonably good depth and fertility of topsoil considerably slow down the transition of erosion phases and its impact on productivity levels over time, as reflected by only a small change in annualized net returns over the 50-year planning period.

However, judged from the point of view of sustaining both farm income and land resource quality for a prolonged time, the analyses of long-term on-farm economic effects of the moderate cropland erosion rates in the black soil zone clearly indicate economic benefits from soil conservation. In areas with higher erosion rates, the benefits would be much greater. Favorable cost-effectiveness through technological development of conservation tillage systems in the future, is also expected to sufficiently enhance the economics of soil conservation and induce adoption.

Since farm-level decisions are generally made under short-run planning horizons using short-run evaluations of information, the higher present-value net returns shown in the 1-year analysis, rationalize the choice of the prevailing cropland management in the black soil zone. However, decisions to adopt conservation management should be based on the long-term on-farm economic consequences.

Finally, with respect to implications for public policy, the results indicate that on-farm economic incentives for farmers in the black soil zone to adopt erosion control measures are weak and insufficient both in the short- and the long-run. In the public interest of controlling farmland degradation, and much larger off-site sediment consequences, government intervention appears imperative. This should take the form of financial incentives (subsidies, tax rebates) to compensate for incremental costs of soil conservation in the short-run, and investment in research and technology transfer of cost-effective methods of soil conservation in the long-run.

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[1] Shankar Narayanan is a research economist with Farm Finance and Resources Division, Agriculture Canada. This article summarizes a working paper prepared by the author under the same title.

[2] The alternative conservation management system was selected on the basis specified from among three options: till-plant; no-till; and contouring.

[3] In the execution of the model, some amendments to the model alogarithm were made in order to provide the capitalized land value estimates directly and to correct for annuity calculation (see working paper for details).

[4] Tolerance level represents annual long-term soil loss rate consistent with indefinite sustenance of soil productivity. No official benchmark soil loss tolerances for prairie or other regions in Canada exist. In the U.S., soil loss tolerances vary between 5 and 11 t/ha per year (Wischmeyer, 1978).

[5] It is assumed that the on-site tillage/support practice conditions have no impact on wind erosion control.

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Canadian agricultural land supply and quality in global perspective

J.S. Henderson and J. Ruel[1]

INTRODUCTION

Over the centuries the treatment of agricultural land in the writings of economists has undergone a considerable evolution. Since the 1700s when Quesnay and the Physiocrats traced all economic surplus back to land and hence emphasized the primacy of agriculture, we have witnessed a progressive decline in the perceived importance of land and agriculture. As other sectors developed, land came to be viewed as just one among a host of equally important inputs to production activities. But despite the modern technical treatment of land on the part of economists, the basic truth of physiocratic thought is inescapable — agriculture feeds the world and makes it possible for people to engage in economic activities other than food production. It follows that the land base sustaining the agricultural sector is not merely one more factor of production, but rather a vital resource without which virtually all economic activity would cease. One author has described it as the "... foundation not only of agriculture, but of civilization itself".[2]

Yet despite the paramount importance of agricultural land and soils, much of the world is witnessing the progressive, accelerating deterioration of the agricultural land base. Urbanization and other forms of loss and degradation such as wind and water erosion, salinization, acidification and desertification are gradually taking their toll, as the potential land base for agriculture shrinks and its average quality declines. At the same time, populations continue to grow, particularly in chronic food-deficit nations, many of which are not particularly well-endowed with agricultural resources or strong industrial bases; many such countries find it increasingly difficult to support the costs of food imports and must rely on the international community for food aid. This situation is expected to worsen over the balance of this century, despite apparent large reserves of unexploited lands, historical upward trends in yields and productivity, and food surpluses in developed countries.

Similarly, there is sufficient reason to believe that the accelerating growth in world agricultural trade will continue on the strength of existing production and demographic trends, and because of the unbalanced distribution of population relative to global agricultural land resources — particularly those unexploited lands with arable potential. Consequently, it is worthwhile to compare the Canadian agricultural land situation with the rest of the world and to assess the possible trade implications of global and domestic trends in land use and degradation.

CANADIAN SITUATION

Canada and much of the developed world share a similar set of land-based resource problems. Although a large country and one which Canadians themselves have long and mistakenly viewed as the breadbasket of the world, Canada does not possess vast reserves of land just waiting to be cleared or drained, and cultivated. Out of 922 million hectares (excluding inland water-covered areas), only about 48.6 million fall within Canada Land Inventory (CLI) classes 1-3 for agriculture, which are lands suitable for continuous arable agriculture. In fact, only about 45.6 million hectares are actually available after subtracting the area taken up by roads and farm buildings.[3] This is less than 5% of Canada's total land area and only slightly less than the actual improved farmland area recorded in the 1981 Census, but approximately 10 million hectares greater than the combined area of crops and fallow in 1981. Hansen has argued that this 10 million hectare margin of good class 1-3 land will probably not be completely cropped until sometime between 2015 and 2024. If we consider the possibility of upgrading class 4 land through land improvement, and if we allow for reductions in summerfallow, the effective margin on which to expand cropland area may, in fact, be considerably larger. In short, there is no farmland supply crisis in Canada at present, nor does one appear to be imminent. However, some would argue that there is a crisis in certain small areas such as the Niagara fruitlands where there is growing concern over the potential loss of the only areas in Canada suitable for such crops as peaches, cherries and grapes. Many of the affected crops already face stiff competition from cheaper imports, and the lands in question may well yield much higher net public benefits from alternative uses. Retention of these areas for agriculture imposes opportunity costs on society that are large and not to be neglected in the analysis. Policy makers, therefore, must decide whether loss of such lands constitutes a crisis.

Although there appears to be enough class 1-3 land in Canada, there is reason to be concerned about its average quality, which is being impaired by soil degradation. Several recent studies and reports have documented the extent and severity of this problem in the various regions of the country.[4,5,6,7] The on-farm effects of soil degradation are estimated to cost Canadian producers between $698 million and $915 million annually, primarily due to higher input costs and reduced yields. Together with the off-farm costs of pollution and sedimentation, the total direct cost of soil degradation is estimated to be $1-1.4 billion per year.

These recurrent annual costs do not yet seriously threaten our international trading position, but they do contribute substantially to the financial hardships many of our producers are experiencing. Not only does soil degradation force producers to purchase increasing quantities of expensive soil amendments to replace the natural elements lost through erosion, but it ultimately leads to lower land values that cause losses in capital. Consequently, there are two compelling reasons for landowners to take soil degradation seriously: deteriorating soils are more difficult and expensive to manage and more vulnerable to weather, thus increasing the risks of farming in the short term; and, in the long term, a landowner's retirement security may be undermined by the insidious effect of degradation that eventually lowers income potential and, therefore, land value.

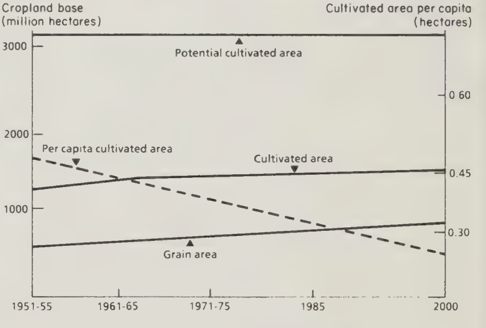
Agriculture Canada is taking the problem of soil degradation very seriously, having identified it as one of the most important issues in Canadian agriculture, along with farm finances. The growing awareness of the need to practise a physically sustainable and economically viable form of agriculture, matched with the high priority accorded these concerns by the federal and some provincial governments and the private sector, bodes well for the future. Practicable and profitable solutions in many cases are well understood and are being promoted and adopted. This applies to such practices as cross-slope plowing, reduced tillage, better soil cover management, greater use of crop rotations and green manures, planting of windbreaks and reductions in summerfallow where feasible. However, progress has been slight compared to the magnitude of the problems we are facing. For example, less than 6% of New Brunswick's highly erosion-prone potato lands are protected by some form of conservation. In the prairie region, some 3.8 million hectares of agricultural land in the black and gray soil zones, where moisture levels are generally adequate, were summerfallowed according to the 1981 Census; this indicates that there continues to be considerable scope for improving the protection of our soil resources from wind and water erosion.

GLOBAL LAND RESOURCES FOR AGRICULTURE

Both in Canada and around the world, most of the best land for agriculture is already in production. Reserve lands will be developed for the most part only at substantial economic and environmental cost and only over the long term. Estimates of current and potentially arable cropland appear in Table 1. Global land area net of inland, water-covered, areas is 13 081 million hectares, of which 1472 million (or just 11%) was cultivated in 1983.

Much of this land is unsuitable for cultivation, but with sufficient time and investment in clearing, drainage and other capital improvements, the cropland base, excluding pastures, could potentially be expanded to 3031 million hectares according to Dudal,[8] 3200 million hectares according to Revelle,[9] or perhaps as much as 3419 million hectares according to Buringh.[10] Reserves therefore exceed the total area currently in production. However, as the figure indicates, actual cultivated areas are not projected to increase substantially over the balance of this century if

ACTUAL AND POTENTIAL GLOBAL CULTIVATED AREAS



Source: Global 2000: The Technical Report, Volume 2

TABLE 1 WORLD LAND RESOURCES FOR AGRICULTURE (MILLION HECTARES)

	North America[5]	Central America[6]	South America	Africa	Europe	USSR	Asia	Oceania	World
Land area[1]	2031	108	1753	2966	473	2227	2679	843	13 081
Potentially arable area[2]	460	20	672	736	160	352	640	160	3 200
Cropland[1,3]	260	13	139	183	140	232	456	48	1 472
Reserve arable lands	200	7	533	553	20	120	184	112	1 728
Exploitation ratio[4]	.57	.65	.21	.25	.88	.66	.71	.30	.46

[1] *1984 FAO Production Yearbook*, Vol. 38
[2] Based on Revelle, R. (1984), *The Resourceful Earth*
[3] Excludes permanent pasture; includes fallow; lands cropped more than once per year counted only once
[4] Cropland/Potentially arable area
[5] Canada, U.S., Mexico
[6] Includes Caribbean

present trends hold. It is unlikely that world cultivated area will exceed 1550 million hectares before population passes the 6.3 billion mark, the United Nations' intermediate estimate for year 2000. As the figure illustrates per-capita cultivated area has been declining steadily and will have been reduced by more than 50% to about 0.25 ha/person during the last half of this century.

Despite declining per-capita cropland area, world food production continues to grow faster than the population. Between 1975 and 1984, the world population increased 17% while global food production rose 22.8% (1984 FAO *Production Yearbook*). Among other factors leading to global gains in world production, the most important has been increasing yields. This will continue to be true; only in Latin America is expansion of cultivated area expected to contribute more to increasing agricultural production than will increasing yields (Table 2).

TABLE 2 SOURCES OF INCREASED AGRICULTURAL OUTPUT, 1980-2000

Region	Cultivated land area growth (%)	Multiple cropping (%)	Increased yields (%)
90 countries	26	14	60
Africa	27	22	51
Far East	10	14	76
Latin America	55	14	31
Near East	6	25	69

Source: FAO, *Agriculture Toward 2000*

Productivity gains frequently lead to increased pressures on the land and environment as production intensifies and output is forced upwards by increased use of chemicals, higher planting densities, reduced reliance on rotations and greater use of mechanical rather than animal traction. At the same time, the widespread use of a relatively small number of high-yielding varieties has resulted in a drastic reduction in the genetic variability of world crops, and the loss of scores of traditional, well-adapted local varieties that tend to perform better under adverse conditions. World food production is therefore becoming more vulnerable to climatic and human-induced disturbances.

The global cropland base is not static. Both the quantity and quality of the world's cultivated lands fluctuate continually in response to factors such as farm income, urban encroachment, new land development, land upgrading and degradation, and deliberate policy actions such as land set-aside programs. A report by the Organization for Economic Cooperation and Development (OECD) on the state of the environment in 1985 indicated that the area of cultivated and permanent cropland is declining throughout most of Europe and in Japan, is reasonably stable in Finland, Norway, Ireland, the United Kingdom and the United States, and is increasing in Australia, New Zealand and Turkey. In comparison, Statistics Canada data indicate that Canadian improved farmland has been increasing slowly. The developed countries now account for about 27% of the world's best agricultural land, but a declining share — at just 17% — of the world's population.[11]

Urbanization is reducing both actual and potential cropland areas. Annual losses are small in most developed countries relative to total potential cropland, but the lands in question are frequently among the very best available for agricultural production. In Europe, close to 90% of the potentially arable area has already been developed for agriculture. This leaves a small margin of reserve lands potentially available to replace lands lost to urban expansion or other non-agricultural uses (Table 1). In the United States, recent estimates of farmland conversion support the view that such losses are not as large as earlier estimated in the National Agricultural Lands Survey, which set the rate at 1.2 million hectares per year.[12] Hart, for example, estimates the loss of cropland through urbanization was less than 200 thousand hectares annually from 1970 to 1980, while urbanization proceeded at an average rate of 1.27 million hectares annually for the same period.[13] Other authors echo similar sentiments.[14,15,16]

For the OECD as a whole, between 1% and 3% of agricultural land area was converted to urban uses during that period,[17] but reserve lands in OECD member countries remain substantial overall.

The picture is less clear in the developing countries because of very poor data. It is known that urbanization is occurring very rapidly, with many large cities experiencing annual growth rates in excess of 6%. Brown has calculated that expanding cities will absorb 25 million hectares of cropland by the end of the century,[2] but this represents only about 1.5% of the world's reserve arable lands, or less than 2% of the present cropland area.

A more serious threat to the world's food production potential is posed by a combination of physical and socioeconomic factors which collectively are resulting in the loss or abandonment of large areas of once-productive agricultural land.

Among socioeconomic factors, one could list low commodity prices, subsistence farm incomes, small farm size, limited access to farm inputs and credit, and the lure of urban lifestyles and opportunities. These, together with physical factors such as erosion, soil waterlogging, salinization, overgrazing and desertification, have made agriculture unattractive, unprofitable or physically impossible in many areas. Dregne estimates that some 20 million hectares annually are deteriorating to a level of zero or negative net returns, including 2 million hectares of rainfed cropland, and 546 thousand hectares of irrigated land.[18]

The American *Global 2000* report found that at current rates, desert areas would expand 20% by year 2000, but found reason to believe that the rates were accelerating.[19] Consequently, there is potential for a dramatic global increase in ruined agricultural land, with some 2.5 billion hectares (mostly rangeland) facing high or very high risk of turning into desert.[18,20]

As once-productive agricultural lands progressively deteriorate, there are three principal ways to maintain or expand production: develop new lands for agriculture; farm existing lands more intensively, including expansion of irrigated areas; or rehabilitate degraded lands. Dudal has argued that even with the widespread adoption of conservation measures some 200 million hectares of new land would need to be put into production by the year 2000 just to meet the world's growing food requirements. Without conservation these new lands would merely substitute for lost soil without leading to any increase in food production.[8]

The figure projects cultivated areas to year 2000. Irrigated area in 1985 is approximately 265 million hectares and may reach 300 million by the end of the century. This land is particularly valuable because it accounts for a disproportionate share of production. However, close to half of the world's irrigated land has been seriously affected by salinity, alkalinity and waterlogging. These problems are becoming worse and can also be expected to affect newly irrigated lands.[19]

China, with a relatively small arable land base (roughly 11% of the land area) has been attempting to increase cereal production through intensification. Irrigated area has expanded from 18.5% of cropland in 1952 to 45.4% in 1985.[21] Despite marked gains in cereal production, the world's largest producer of grain, cotton and oilseeds faces continued low per-capita production, serious and growing problems of degradation, and barely adequate, possibly declining, average food consumption.[22] The record wheat harvest of 1984 was followed by a 7% decline in 1985 attributed to the effects of drought.

GLOBAL SOIL DEGRADATION

From a global perspective, agricultural land degradation gives cause for genuine concern. Erosion and desertification are widespread and increasing. Left unchecked they will have a dramatic impact on rain-fed cropland area. A Food and Agriculture Organization (FAO) study of 117 developing countries (not including China or Korea) found that, without conservation, such croplands would shrink by 18% over the balance of this century — a loss of 544 million hectares.[23] That is an area greater than the total potential arable cropland of Europe and the Soviet Union combined. Arable land still in cultivation would also be less fertile, so that the overall reduction in productivity could be as high as 29% for rain-fed agriculture.

About 44% of the world's land surface is now desert, an area of about 57 million square kilometres. This includes 9 million square kilometres of human-induced deserts,[11] caused principally by intensive farming, overgrazing, forest cutting and excessive withdrawal of groundwater. Droughts, even when prolonged, are not a major cause of spreading deserts in Africa or elsewhere, although they can exacerbate the effect of those factors already mentioned.

Among OECD countries most affected by desertification are the U.S., Turkey, Australia and Spain. Dregne found that of the 450 million hectares of arid lands in Canada, the United States and Mexico, two-thirds was moderately desertified and less than one-third severely desertified. Canada's share of these affected lands is relatively small at just 3.2% (about 3 million hectares), most of which is rangeland in the southern prairies. The U.S. and Mexico account for 308.5 million hectares, including 24.5 million hectares of cropland. Just under 30% of the total area affected is classed as severely or very severely desertified — all of it in the U.S. and Mexico.[18]

Elsewhere, the problem is serious in Africa, Australia, the Middle East, western China, south-central India, Mongolia, south-central USSR, and in large areas of western Argentina, Brazil and Chile. Dregne estimates that, worldwide, it affects 400 million people. Expressed in terms of its effect on agricultural output, desertification results in a loss equivalent to the total annual wheat crop in Canada, or enough to meet the total caloric requirements of about 80 million people.[18]

The global loss of topsoil as a result of water and wind erosion has been calculated by Brown to be 23.4 billion tonnes per year in excess of new soil formation.[24] Table 3 provides comparative loss estimates for the United States, India, China and the USSR. The data are very rough, probably conservative estimates, based largely on sediment loads in major river systems, and represent average figures. In the U.S., less than 9% of the cropland area

TABLE 3 ESTIMATED EXCESSIVE EROSION OF TOPSOIL FROM WORLD CROPLAND

	Topsoil Loss in Excess of New Soil Formation (million tonnes)	(t/ha)
China	3 636	36.7
India	4 727	33.8
USSR	2 273	9.1
United States	1 527	9.1
Rest of world	11 227	18.5
Total	23 390	18.5

Source: Adapted from Brown, L.R. (1984), The Global Loss of Topsoil. *Journal of Soil and Water Conservation*, May-June

accounts for 70% of the eroded topsoil, while 60% experiences erosion at tolerable rates (Table 4). At the same time, surveys by the Conservation Tillage Information Center in the United States indicate that more than one-third of all U.S. cropland is at least partially protected by some form of conservation tillage, and that the rates of adoption of such technologies are high and increasing. These and other indications of progress have led some critics of the *Global 2000* report to downplay the seriousness of erosion in the United States, and to conclude that "the largest social cost of soil erosion is not the loss of topsoil, but rather the silting-up of drainage ditches in some places, with consequent maintenance expenses".[25]

TABLE 4 TOPSOIL LOSS FROM UNITED STATES CROPLAND

Soil loss (t/ha)	Percent of cropland	Percent of excess loss
0 – 11.2	60.2	0
11.2 – 22.4	19.9	8
22.4 – 44.8	11.3	22
44.8 – 112.0	6.8	37
112.0 – 224.0	1.4	18
224.0 +	0.5	15

Source: National Resources Inventory, 1982

Both China and India are experiencing high rates of topsoil erosion (Table 3). Some of the most extensively eroded soils in the world are found in China's Northwestern Loess Plateau, where annual soil losses in some locations exceed 300 tonnes per hectare, according to Lee.[26] Only the great depth of soils over much of this region has forestalled major losses of cropland area.

Together, China and India account for about 40% of the world's population, and experience a combined annual loss of about 8400 million tonnes of topsoil. This is approximately equivalent to 3.7 million hectares of cropland (or 8% of Canada's cropland area), assuming an average of 150 t/ha of soil on a dry matter basis for each centimetre of depth, and an average topsoil depth of 15 cm. These high rates of loss cannot be sustained indefinitely; simple calculations indicate that if losses are confined to 40% of the cropland area, annual average losses of 87 t/ha could be physically sustained for perhaps 50 years, under the assumption that soils are, on average, twice as deep as the world average. Economically sustainable production might not last for 50 years before it becomes necessary to abandon arable agriculture in favor of pasture or non-agricultural uses.

In China and in much of the developing world, the shortage of fuel wood exacerbates the soil degradation problem. Contrary to former practice and unlike their counterparts in Europe and North America, modern Chinese farmers do not generally return crop residues to the soil, which consequently eliminates an important source of organic matter. Up to 75% of China's straw is burned for fuel.[22] Extensive past reliance on night soils and farmyard manures is being supplanted by a growing reliance on chemical fertilizers and the spread of mechanization. Concomitant with these trends is the rapidly increasing problem of pollution of surface and groundwaters by nitrates and other pollutants. Overall, Smil found that the combination of erosion, desertification and urbanization has reduced China's arable land base by 11% since 1957.[22]

Elsewhere, degradation is particularly severe in the Andes, northeast Brazil, El Salvador, Guatemala, Haiti, the Sahelian countries, the Horn of Africa and east Africa, much of southwest Asia and Afghanistan, parts of south Asia, Java and the Philippines.[23] Some of the affected countries possess large reserves of potentially arable land and are not considered at high risk in their ability to meet their own basic food requirements. Others have a bleeker outlook and will become progressively more dependent on imports, including food aid.

In Africa, the situation with respect to agricultural land degradation is particularly alarming. Only 19% of the land area has soils with no inherent fertility limitation, while 36% of the continent is covered in coarse-textured soils, desert, and semi-desert soils.[23] Unchecked degradation is projected to threaten Africa with the loss of 203 million hectares of potential rain-fed cropland by year 2000, an amount greater than the 1983 cropland area. FAO projections based on an analysis of population-supporting capacities of 117 developing countries indicate that degradation in 64 of those countries will be critical for low levels of inputs and technology, with populations in excess of their supporting capacities. Some 29 of these countries are in Africa; their projected combined population in 2025 is estimated at 875 million.

Table 5 presents a list of 50 critical developing countries selected from among the 117 in the FAO study of population-supporting capacities. Declining food self-sufficiency ratios for most of these countries provide strong *a priori* evidence that world agricultural trade, including food aid will continue to increase throughout this century and into the next. From the evidence in Table 5, there is clearly scope for expanding Canadian markets in many of these countries, but success will depend far more on the ability of prospective importers to pay, than on Canada's ability to compete with most major competitors.

On average, world trade in cereals is about 200 million tonnes annually, of which imports by low-income, food-deficit nations account for about 25%. In 1984, 20% of the cereals imported by such countries was received as food aid rather than commercial imports, and there is little reason to expect the aid share to decline.

TABLE 5 TRADE-RELATED PARAMETERS FOR SELECTED CRITICAL COUNTRIES

Country	Population		Per capita income[3]		Food self-sufficiency[2]		Agricultural imports from Canada, 1983[4]	
	1984[1]	2025[2]					Food and live animals	Cereals
	(millions)		(U.S.$)	(year)	1978	2000	(U.S.$ millions)	
Afghanistan	14.3	42.1	168	1978	.97	.57	—	—
Algeria	21.3	62.9	1 951	1982	.40	.35	192.5	107.5
Bahrain	0.4	0.8	6 315	1980	—	—	0.2	0.03
Bangladesh	98.5	222.0	119	1983	.95	.77	63.2	62.7
Benin	3.9	13.9	310	1982	.95	.93	—	—
Bhutan	1.4	—	100	1981	—	—	—	—
Botswang	1.0	3.4	544	1978	—	—	—	—
Burkina-Faso	6.8	20.5	180	1981	.95	.75	—	—
Burundi	4.5	3.4	235	1982	.99	.87	—	—
Dominican Rep.	6.1	—	1 221	1980	.77	.67	13.1	0.04
El Salvador	5.4	15.0	854	1984	.85	.66	1.2	0.3
Ethiopia	35.4	93.6	117	1980	.99	.68	16.3	16.3
Guatemala	8.2	—	1 085	1984	.84	.78	1.2	0.06
Haiti	6.4	18.3	300	1983	.84	.55	5.3	0.04
Iran	43.8	99.0	2 160	1973	.75	.59	123.9	108.7
Iraq	15.2	40.4	2 410	1981	.49	.33	89.5	89.5
Israel	4.2	7.5	5 609	1983	—	—	26.7	25.2
Jordan	3.4	11.2	552	1976	.13	.18	2.9	2.8
Kenya	19.8	82.3	196	1981	1.01	.62	1.0	0.2
Kuwart	1.7	5.0	11 431	1975	—	—	0.8	0.07
Lebanon	2.6	5.6	1 150	1983	.18	.13	5.6	5.2
Lesotho	1.5	3.7	355	1979	—	—	—	—
Malawi	6.8	23.0	220	1979	1.01	.67	—	—
Mali	7.8	25.0	140	1981	.94	.59	—	—
Mauritania	1.8	6.1	466	1984	.32	.39	2.9	2.9
Mauritius	1.0	1.6	1 052	1981	.40	.70	0.05	—
Morocco	22.8	59.3	800	1981	.77	.66	1.2	—
Namibia	1.5	3.3	—	—	—	—	—	—
Niger	5.9	20.5	475	1981	.92	.87	—	—
Nigeria	92.0	285.0	750	1980	.98	1.01	15.6	6.0
Oman	1.2	2.9	2 400	1976	—	—	—	—
Philippines	53.4	108.0	772	1982	.96	1.01	3.8	0.001
Puerto Rico	3.4	6.5	—	—	—	—	—	—
Qatar	0.3	0.7	35 000	1982	—	—	0.1	—
Rwanda	5.9	19.6	250	1982	.99	.85	—	—
Saudi Arabia	10.8	31.0	11 500	1979	.12	.10	11.1	7.2
Senegal	6.4	16.8	342	1975	.55	.34	3.1	1.9
Sierra Leone	3.5	10.7	176	1980	.92	.76	0.5	0.5
Somalia	5.4	13.4	500	1983	.59	.34	0.6	0.6
Sri Lanka	16.1	26.8	266	1981	.71	.90	30.2	29.9
Swaziland	0.6	1.9	840	1981	—	—	—	—
Syria	10.2	32.7	702	1975	.89	.63	59.4	58.0
Togo	2.8	8.9	348	1981	.95	.73	2.7	2.7
Tunisia	7.0	13.1	844	1983	.61	.72	0.5	0.2
Uganda	15.2	51.9	240	1976	1.00	.86	1.6	1.5
United Arab Emirates	1.3	2.0	24 000	1981	—	—	0.7	0.002
Vietnam	58.3	106.0	189	1982	.92	.71	0.02	—
Yemen, A.R.	6.4	16.3	475	1978	.69	.71	—	—
Yemen, P.D.R.	2.1	5.6	310	1977	.25	.23	0.7	0.6
Zimbabwe	8.5	28.4	500	1981	1.02	.63	0.3	0.2

[1] *1984 FAO Production Yearbook*, FAO, Rome

[2] *Land, Food and People*, FAO, Rome

[3] *The World Almanac 1986*, New York

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CONCLUSIONS

The global outlook for the agricultural resource base is not good in the short run. The wealthier nations are in a comparatively better economic position to adjust their practices and so conserve soil resources; in most cases this is the only viable option because there is little available land with potential for arable agriculture that has not yet been utilized.

Poorer nations have much less capacity to sustain the costs of conservation, particularly when the costs occur years before the benefits begin to accrue. In many cases, these nations are at or near the limits of potentially cultivable area. Southwest Asia has more land under crops than is considered suitable for cultivation; cultivated areas in Southeast Asia amount to 92% of potential cropland. Only in the USSR, North America, South America, Oceania and Africa are there substantial reserves with some potential, but the economic and environmental cost of bringing these into production all but preclude their rapid development. Massive, capital-intensive water diversion schemes would be necessary in the USSR and North America to exploit the potential.

In South America, the expansion of cultivated areas will be at the expense of rain forest destruction. Rain forest soils are highly vulnerable to oxidation and weathering. It is not clear that they can sustain arable agriculture, and production systems have yet to be adapted. Allaby, for example, does not believe that rain forest soils can ever be domesticated;[27] if this proves to be the case, estimates of potentially arable land in Africa and South America will be far smaller than those in Table 1.

From a Canadian perspective, we cannot afford to be complacent just because we are not alone in facing the threat of land degradation. Canada is better placed than most countries to meet the challenges posed by erosion, salinization, desertification and compaction. However, if we fail to do so while the United States and other competitors succeed, then we will not maintain a competitive position in world markets or be able to take advantage of market opportunities in food-deficit nations. Although we may face higher short-term costs of production as we absorb the costs of conservation investments, our future share of an expanding world trade in agricultural commodities provides good incentive to get on with the task. We have adequate reserves of good-quality land that can be brought into crop production as market conditions dictate, and steps are being taken to protect the agricultural resource base through the identification and use of sustainable management practices. Therefore, despite the gravity of the problem, there is reason for optimism about Canada's ability to maintain a competitive position in world markets.

Nevertheless, the challenge remains, and the task has only just begun. To maintain the natural productive capacity of the resource base, much more needs to be done in the areas of land use regulation, sustainable productivity enhancement, and integrated resource-use planning. Building an agricultural sector that reflects the principles of sustainable production, renewable resource protection and sound environmental management will pay long-term dividends to both producers and consumers, and to present and future generations of Canadians.

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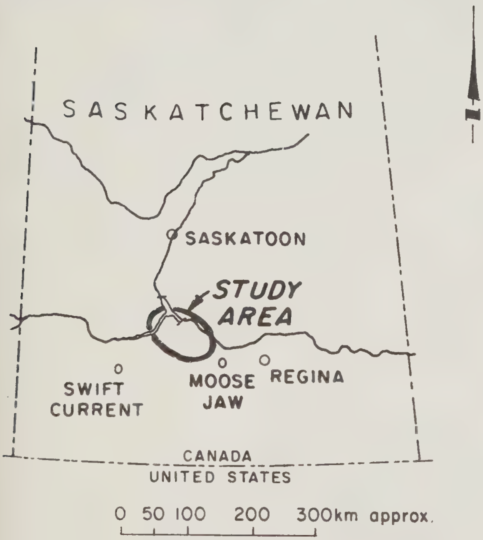
Riverhurst East Irrigation Study

D.M. Boyle[1]

INTRODUCTION

The Riverhurst East Irrigation Study was carried out by the Prairie Farm Rehabilitation Administration (PFRA) of Agriculture Canada in conjunction with Saskatchewan Agriculture, the Saskatchewan Water Corporation, and Ducks Unlimited.[2] The request for the study and the overall direction was provided by a steering committee led by farmers who represent the growing interest in the area for group irrigation development. Extensive input was provided by way of a local public participation process. The study reports on the agricultural and engineering feasibility, economic viability, and social and environmental acceptability of large-scale irrigation development on the southeast side of Lake Diefenbaker (Figure 1).

FIGURE 1 LOCATION MAP



The study area, as outlined in Figure 2, involves a gross area of about 54 600 ha of soils generally classified as suitable for irrigation. The potential for irrigation is split into two distinct regions. The northern region is along the east side of Lake Diefenbaker and south of the Qu'Appelle Valley, and the southern region follows the Thunder Creek system down to the Mortlach area. The area includes six rural municipalities from which local groups petitioned potential irrigation areas totaling about 37 000 ha.

Having a semiarid continental climate, the area has average annual precipitation of 377 mm, of which 64% occurs during the growing season. In the growth of cereal crops, potential seasonal evapotranspiration averages 560 mm, resulting in a deficit of about 230 mm. Both the lack of water and the timing of the water shortage affect yields. The growing season varies from 165-189 days, during which 1630-1750 degree-days above 5°C are accumulated. The frost-free period varies from 90-110 days.

Water resources in the area consist of surface runoff, the Thunder Creek system, numerous intermittent streams, and the flows from the South Saskatchewan River into Lake Diefenbaker. With 20% of the annual precipitation occurring in the form of snow, local runoff is unreliable in frequency and volume. A dependable supply of irrigation water can only be supplied from Lake Diefenbaker.

Lake Diefenbaker was constructed, during the period 1958 to 1967, with the primary goal of providing irrigation water for over 200 000 ha and for providing a dependable supply of water for municipal, industrial, hydroelectric and recreational purposes. At full supply level it has a 9.4 million dam^3 storage capacity and floods a surface area of 42 900 ha.[3] Live storage represents about 43% of total storage. Median runoff volumes into Lake Diefenbaker total 8.7 million dam^3. About 90% of the total net inflow is used by the Saskatchewan Power Corporation to generate peaking power, mainly in the winter. Major diversions from the reservoir, for the East Side Irrigation Pumping Plant and for the Qu'Appelle River, total about 3% of the median flow. The peak diversion for the proposed Riverhurst East Project is expected to be about 2% of the median flow.

Within the study area, approximately 121 400 ha were assessed for irrigation suitability through on-site inspection and soil map interpretation. Of this total area, 45% of the soils were classified as class 1, 2 and 3 land suitable for irrigation, and 55% class 4 land not suitable for irrigation. To allow for irregularly shaped fields, roads, yards, etc., it was estimated that the net irrigable area at full development would be 35 500 ha.

PROJECT DESCRIPTION

The main concept shown by Figure 2, referred to as the "Regional Development Scenario", would involve one intake and pump plant on Lake Diefenbaker to deliver water throughout the study area by way of open canals and balancing reservoirs. The alternative concept, called the "Local Development Scenario", would involve construction of individual intakes and pump plants to serve one or more components of the study area. Table 1 lists the scenarios and the net potential areas. Table 2 provides, in present-value terms, project costs for the various water supply alternatives.

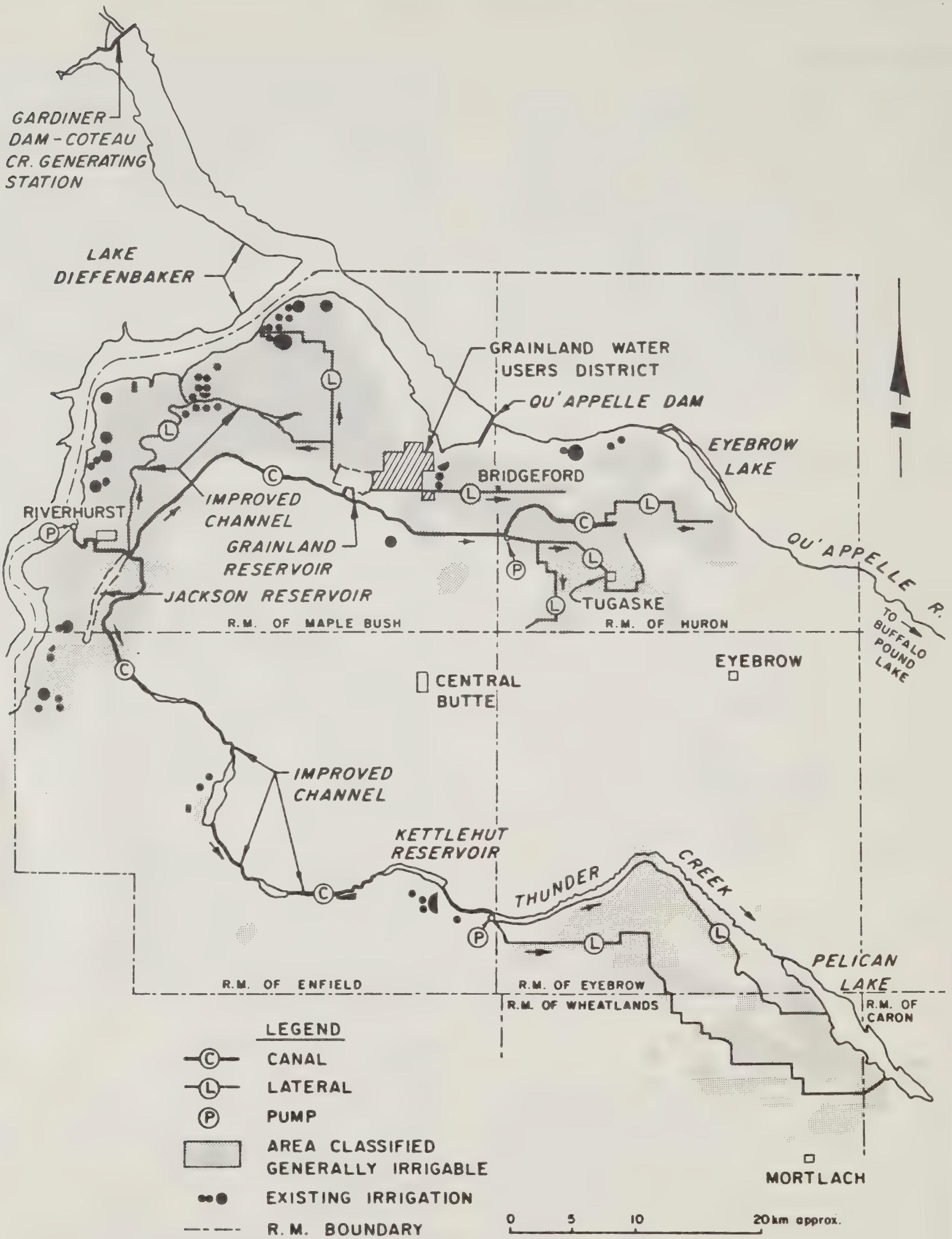

GARDINER DAM - COTEAU CR. GENERATING STATION
LAKE DIEFENBAKER
GRAINLAND WATER USERS DISTRICT
QU'APPELLE DAM
EYEBROW LAKE
BRIDGEFORD
IMPROVED CHANNEL
RIVERHURST
GRAINLAND RESERVOIR
JACKSON RESERVOIR
TUGASKE
QU'APPELLE R.
TO BUFFALO POUND LAKE
R.M. OF MAPLE BUSH
R.M. OF HURON
EYEBROW
CENTRAL BUTTE
IMPROVED CHANNEL
KETTLEHUT RESERVOIR
THUNDER CREEK
PELICAN LAKE
R.M. OF ENFIELD
R.M. OF EYEBROW
R.M. OF WHEATLANDS
R.M. OF CARON
MORTLACH
LEGEND
CANAL
LATERAL
PUMP
AREA CLASSIFIED GENERALLY IRRIGABLE
EXISTING IRRIGATION
R.M. BOUNDARY
0 5 10 20 km approx.

TABLE 1 IRRIGATION DEVELOPMENT SCENARIOS

Scenario	Irrigation block	Net hectares
Regional Development (contour & section-line routes)[1]	Mortlach	9 955
	Riverhurst	7 335
	Grainland	7 575
	Main Canal	2 000
	Tugaske	4 515
	Eyebrow West	1 745
	Bridgeford	2 380
	Total area	35 505
Local development	Bridgeford-Tugaske	6 325
	Riverhurst	8 050
	Grainland	5 340
	Riverhurst-Mortlach	18 000

[1] For the Regional Development Scenario, two methods of routing the main canal were considered. Due to topographic constraints, final canal location would likely involve a combination of the two routes.

The Local Developments, on a unit area basis, would be slightly less expensive to construct. However, studies to date indicate that other factors may favor the Regional Development Scenario, including the total area served, annual operating costs, flexibility of operation and possible future expansion options. At full development, the Local Developments could supply about 84% of the area supplied by the Regional Development.

ECONOMIC CONSIDERATIONS

Analyses carried out as part of the economic considerations for this study include: agricultural profile of the study area; farm-level economics; and project-level economics. The farm-level analysis provides information concerning the financial feasibility of irrigation from an individual farmer's standpoint, while the project-level analysis considers irrigation benefits and costs at the local, provincial and national levels.

Agricultural profile

The agricultural profile was constructed using data from the 1981 Census of Agriculture. Characteristics of land use, land ownership, farm operations, farm capital values, crop and livestock production, irrigation on farms and farm labor were determined from this profile. In addition, land use in 1984 was compiled for PFRA from a Landsat image prepared by the Manitoba Remote Sensing Centre.

In 1981, there were 844 farms in the study area, averaging 514 ha each. Approximately 70% are comprised of more than 300 ha, with 25% having more than 650 ha. Land in the study area was defined as 78% improved, of which 52% was cropped, 41% in summerfallow, 6% in pasture, and 1% in other uses. The high level of summerfallow exists in the crop rotation as a means of conserving moisture. Land was 68% owned and 32% rented. The total value of farms averaged $995/ha, comprised of $793/ha for land and buildings, $156/ha for machinery and $46/ha for livestock. The total value of all farm capital assets was $414 million in 1981. The average value of sales was $48 883/farm.

Wheat was the major crop grown, accounting for 79% of the cropped area in 1981. Other crops included barley at 5% and oats and rye each at 3% of the area. Forage crops accounted for 9% of the cropped area. Livestock production in the area has declined by 47% since 1976 to 35 721 head of cattle in 1981.

The economic structure is that of a rural hinterland linked to the Regina-Moose Jaw urban region. Farming is the dominant activity. In 1981, the population of the study area was 4390, with the largest urban population of 545 located in Central Butte. Trend analysis for the period 1971-81 indicates that population growth in Caron, stability in Central Butte and declining losses in villages have slowed the overall rate of depopulation of the study area. However, a continuous decline of the rural population has occurred.

Farm-level analysis

The on-farm costs and returns of irrigated crop production were compared with those of existing dryland conditions. Although a number of alternative crop mixes could have been selected for analysis, wheat (predominantly hard red spring wheat) and alfalfa were selected because they were representative of the main crops grown under irrigation in the South Saskatchewan River Irrigation District (SSRID)

TABLE 2 SUMMARY OF PROJECT COSTS[1] ($ MILLIONS)

Cost Component	Present value of project costs					
	Regional Development		Local Development			
	Contour route	Section-line route	Bridgeford-Tugaske	Riverhurst	Grainland	Riverhurst-Mortlach
Capital[2]	200.4	208.5	31.7	31.2	28.9	105.2
O. & M.	24.9	25.7	4.5	3.5	4.3	15.8
Energy	21.0	21.0	4.0	2.9	1.3	14.3
Total cost	246.3	255.2	40.2	37.6	34.6	135.3

[1] All costs are calculated with a 5% discount rate, 15-year on-farm irrigation uptake rate, normal economic conditions, and a 50-year project life. A sensitivity analysis of the variables was conducted.

[2] Capital costs include project works required to provide water without pressure to each quarter section.

No. 1 at Outlook, and for which markets have few limiting factors.[4] Forage was considered to be a basis for additional livestock production although the costs and returns of a livestock production scenario were not examined in this study (see Appendix).

The analysis indicates that irrigated production increases crop yields and gross farm income by as much as four times over dryland production. Dryland yields of wheat on a cultivated area basis average about 0.75 t/ha. These yields are attained with a production system of 40% summerfallow crop, 20% stubble crop and 40% summerfallow. Tame hay yields average 3.2 t/ha.

Corresponding irrigated yields, based on experience in the area and the SSRID No. 1, of wheat is 3.58 t/ha and alfalfa is 10.1 t/ha. The irrigated crop mix includes 75% wheat and 25% alfalfa. Although the future irrigated crop mix is not known, the average situation was assumed to be best reflected in this mix.

Cash operating expenses, including an assumed water delivery charge, would also increase by three to four times over dryland expenses. Net cash income, or the return on the farm operator's labor, management, depreciation and investment, would be as much as five times greater under irrigation. Whether the additional net income generated by irrigation will be sufficient to cover the additional investment and labor costs will depend upon each farmer's financial and management situation.

Irrigation in the study area has potential for profitability, and is likely to be more economically feasible for farmers with low levels of indebtedness and better-than-average management capabilities. The capital cost of irrigation equipment was estimated to be in the range of $1179-1384/ha. The average distance to water and power supply would be about 1.6 km. However, the costs to the farmer included only those within the irrigated parcel of land. Although the project assumes individual one-quarter section center pivots, group developments and larger systems may significantly reduce on-farm and project capital costs. The limiting factors with the larger systems are cash flow and the producer's ability to manage the large amounts of water being pumped.

Table 3 provides a summary of the on-farm irrigation net present values. These are the benefits to irrigation accruing to farmers over the life of the project, net of incremental cash costs and fixed capital requirements. The sensitivities presented include variations in crop prices and on-farm drainage requirements. Sensitivity analyses of uptake rates, discount rates and equipment prices were also conducted. The results were most sensitive to crop prices relative to costs. Increasing discount rates and extending uptake rates affected net present values to a lesser degree. Depending on the texture of soil being irrigated, drainage costs had varying impacts on net present value.

The uptake rate is the number of years it takes farmers to reach the target irrigated area for the project. A longer uptake rate results in a reduction in the present value of the accumulated net benefits. The major factors that will likely affect the rate of irrigation adoption are:

- profitability of irrigation;
- individual financial circumstances;
- age and attitude within the farming community;
- local land tenure circumstances;
- opportunities for integrating and expanding livestock operations; and
- markets, prices, and opportunities for value-added processing.

In general, these factors would likely need special attention by way of appropriate government policies if the irrigation opportunity and benefits from early adoption are to be fully realized. Profitability of irrigation is a function of returns relative to costs. Management is the key factor. Conversion from a traditional wheat-summerfallow rotation to continuous cropping with high levels of inputs, and

TABLE 3 SUMMARY OF ON-FARM IRRIGATION NET PRESENT VALUES[1] ($ MILLIONS)

Sensitivity	On-farm net present values				
	Regional Development	Local Development			
		Bridgeford-Tugaske	Riverhurst	Grainland	Riverhurst-Mortlach
Average crop prices:					
No drainage[2]	63.4	11.3	14.4	9.6	32.3
With drainage	53.4	10.4	13.3	7.2	26.2
Trend crop prices:[3]					
No drainage	114.0	20.3	25.9	17.2	57.8
With drainage	103.8	19.4	24.7	14.8	51.7

[1] Benefits were calculated with the same development assumptions used to compile project costs.

[2] Since on-farm drainage costs are preliminary estimates and actual timing of expenditures has not been forecast, the analysis was performed for both the "with" and "without" drainage conditions. It is expected that the actual cost would be an intermediate of the two.

[3] Projected prices may be obtained by market analysis for the crops grown; however, it is difficult to predict relevant prices in the distant future. The trend analysis, with prices about 20% higher than average prices, was used for a sensitivity analysis of the results.

diverse crop and market opportunities, creates increased pressure on the farm cash flow. Success of the enterprise requires proper planning, willingness to learn new skills, and phasing in additional areas only when profitability is proven on a smaller scale.

Project-level analysis

To determine project feasibility, economic analysis is used to estimate profitability or social return to the entire economy. The economic cash flow procedure is used to determine net benefits. Only the increased economic benefits and costs from the delivery and application of water are included. Present worth is used in the calculation of the benefit-cost ratios. To aid in the discounting of future values and to analyze several combinations of development possibilities, a computer benefit-cost model developed by PFRA was used.

The forms of benefit-cost ratios developed are:

Direct

$$\frac{B}{C} = \frac{\text{PV Benefits} - \text{PV Associated Costs}}{\text{PV Projects Costs}}$$

where: PV Benefits — include the gross incremental returns to irrigation on a present value basis;
PV Associated Costs — include the incremental associated costs to individuals using the water; and
PV Project Costs — include all capital, replacement, operation, maintenance and energy required to provide water without pressure to each quarter section.

Direct-plus-indirect

$$\frac{B}{C} = \frac{\text{PV Value Added (on farm expenditures)}}{\text{PV Projects Costs}}$$

Investment in capital-intensive projects and the resulting increases in agricultural production, purchase of inputs and marketing of the product provide a wide range of benefits to the regional and national economies. Organization and development of a major irrigation project cause substantial expenditures for the purchase of fixed and variable inputs to production. Irrigation requires purchases of agricultural machinery, additional storage space, electrical equipment, pipelines, etc. Increased annual expenditures for fertilizer, chemicals, fuel, hydro, insurance, etc., range from $370-617/ha. The regional economic benefits are due to these increased purchasing activities. The service-oriented base of the local economy also becomes more stable with irrigation. As experienced in southern Alberta, adverse economic effects of periodic droughts are reduced due to consistent production with assured water supplies.

The assessment of regional economic impacts was separated into three components:

— the construction phase;
— the on-farm machinery and equipment purchases; and
— the irrigated production increment.

Table 4 summarizes the changes in value added and employment resulting from the three components. An early version of the PFRA Prairie Regional Input-Output and Employment (PRARIE) Model was used to estimate regional and provincial final demand, employment levels and imports from the rest of Canada.

The benefits of large-scale irrigation projects accruing to society accumulate both directly and indirectly. Table 5 presents direct and direct-plus-indirect benefit-cost ratios. The direct ratios include only the net present value of agricultural production. The direct-plus-indirect ratios include the value-added effects resulting from increased

TABLE 4 SUMMARY OF CHANGES IN VALUE ADDED AND EMPLOYMENT

Project operational component	Regional Development		Local Development			
	Contour route	Section-line route	Bridgeford-Tugaske	Riverhurst	Grainland	Riverhurst-Mortlach
	Value added: Direct-plus-indirect ($ millions)					
Project construction[1]	228.4	238.2	35.7	34.5	33.3	120.0
On-farm investment[2]	59.8		10.6	13.6	9.0	30.3
Increased production[3]	18.7		3.5	4.3	2.8	9.6
	Employment: Direct-plus-indirect (person years)					
Project construction[1]	1690	1776	279	267	254	911
On-farm investment[2]	406		69	91	59	205
Increased production[3]	144		26	33	21	79

[1] Impacts of project construction occur only during the construction period.
[2] Impacts of on-farm investment are the total for the uptake rate of 15-25 years. Replacement of equipment incurs additional impacts. Impacts of on-farm drainage were not included in this table.
[3] Impacts of increased production occur annually, at full development, for the entire life of the project.

TABLE 5 PROJECT BENEFIT-COST RATIOS

Sensitivity	Regional Development		Local Development			
	Contour route	Section-line route	Bridgeford-Tugaske	Riverhurst	Grainland	Riverhurst-Mortlach
			Direct benefit-cost ratios			
Average crop prices:						
No drainage	0.26	0.25	0.28	0.38	0.28	0.24
With drainage	0.22	0.21	0.26	0.35	0.21	0.19
Trend crop prices:						
No drainage	0.46	0.45	0.51	0.69	0.50	0.43
With drainage	0.42	0.41	0.48	0.66	0.43	0.38
			Direct-plus-indirect benefit-cost ratios[1]			
Average crop prices:						
No drainage	1.27	1.22	1.43	1.90	1.37	1.18
With drainage	1.33	1.29	1.47	1.95	1.48	1.25
Trend crop prices:						
No drainage	1.67	1.61	1.87	2.50	1.80	1.55
With drainage	1.73	1.67	1.91	2.55	1.91	1.62

[1] The direct-plus-indirect benefit-cost ratios include the present value of value-added effects of on-farm investment and increased production. Impacts of project construction and operation were not included.

agricultural production and increased agricultural machinery and equipment purchases. These are real gains in production, supported by private expenditures induced by the provision of water. The value-added effects of project construction and operation were excluded from the direct-plus-indirect benefit-cost ratios to allow comparison with other publicly funded projects. The range of direct benefit-cost ratios presented is from 0.19 to 0.69. The direct-plus-indirect benefit-cost ratios range from 1.18 to 2.55.

CONCLUSIONS

The preceding analysis reported on the economic viability of the proposed Riverhurst East Irrigation Project. The analysis followed standard methodology for estimating returns to the economy for water resource development. For comparison, present values of benefits and costs were calculated using a range of discount rates that reflect society's planning horizon. The analytical time frame was set at 50 years, which is equivalent to the minimum expected useful life of the capital works. The effect of changing the project life or the discount rate is not as great as the variation in the results due to crop prices changing relative to costs.

The project benefit-cost analysis demonstrates that many of the benefits of irrigation go beyond the farm to the local community, the province and to other parts of Canada. The direct benefit-cost ratios are based on a hard red spring wheat/forage scenario for which markets are not limiting over the long term. It can be expected that the benefit-cost ratios would be higher under other scenarios which include soft, medium, hard and winter wheats, specialty crops, vegetable crops, livestock production, and agricultural processing (see Appendix). However, production expertise, investment, financing, and marketing become more critical in realizing the potential benefits under these alternative scenarios. Other potential benefits which were recognized but not quantified in the economic analyses include the integrated development by Ducks Unlimited of wetland habitat and potential future water supply for stockwatering, domestic, municipal, and industrial purposes.

Under certain assumptions, the Riverhurst East Irrigation Project was found to be viable for private individuals and society. The question of whether it would be appropriate to provide public funding for this project would depend upon a balancing of regional development and national efficiency objectives. While similar methodology could be employed to facilitate a comparison of alternative expenditure opportunities, such a comparison was beyond the scope of this study.

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[1] D. Merle Boyle is a development analyst with the Policy and Analysis Service, Prairie Farm Rehabilitation Administration, Agriculture Canada. The author would like to acknowledge the valuable input and comments received from G.G. Pearson and W.M. Jones of the PFRA Policy and Analysis Service, and the staff of Saskatchewan Regional Division of the PFRA Engineering Service.

[2] Ducks Unlimited Canada is a private, non-profit, international conservation organization whose goal is to preserve, restore, develop and maintain waterfowl breeding habitat in Canada.

[3] A dam^3 is a cubic decametre, or 1000 cubic metres. It is equivalent to 0.81 acre feet.

[4] Statistics for 1985 indicate South Saskatchewan River Irrigation District No. 1 production may now be shifting away from hard spring wheat to oilseeds and other types of grain.

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APPENDIX

The Riverhurst East Irrigation Project alternatives were also evaluated in a joint Canada/Saskatchewan Irrigation Project Appraisal Study. Although the project costs were the same in both studies, the irrigation development scenarios used different yield, price, production and processing assumptions. The three scenarios in the joint study were called grain, livestock and aggressive, reflecting the different production emphasis in each case. The resulting benefit-cost ratios are presented in the table. The results of the grain scenario are comparable with the results of the PFRA study considering the differences in yield, price and processing assumptions. The livestock and aggressive scenarios represent potentials reflective of the type and level of economic activity that exists within established irrigation districts in southern Alberta and considered to be achievable in Saskatchewan under a comprehensive program of irrigation-based economic development.

CANADA/SASKATCHEWAN IRRIGATION PROJECT APPRAISAL STUDY — BENEFIT-COST RATIOS[1]

	Regional Development	Local Development[2]			
Scenario	Section-line route	Bridgeford-Tugaske	Riverhurst	Grainland	Mortlach
		Direct benefit-cost ratios			
Grain	0.6	0.7	1.0	0.8	0.4
Livestock	1.0	1.1	1.6	1.2	0.7
Aggressive	1.6	1.8	2.5	1.8	1.1
		Direct-plus-indirect benefit-cost ratios			
Grain	1.4	1.5	2.2	1.6	0.9
Livestock	1.9	2.1	2.9	2.2	1.3
Aggressive	2.7	2.9	4.1	3.0	1.8

[1] The benefit-cost ratios were calculated with a 5% discount rate, 15-year on-farm irrigation uptake rate, and a 50-year project life.

[2] The Riverhurst and Mortlach irrigation blocks were evaluated separately in this study.

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Metric units	Approximate conversion factors	Results in:
LINEAR		
millimetre (mm)	x 0.04	inch
centimetre (cm)	x 0.39	inch
metre (m)	x 3.28	feet
kilometre (km)	x 0.62	mile
AREA		
square centimetre (cm^2)	x 0.15	square inch
square metre (m^2)	x 1.2	square yard
square kilometre (km^2)	x 0.39	square mile
hectare (ha)	x 2.5	acres
VOLUME		
cubic centimetre (cm^3)	x 0.06	cubic inch
cubic metre (m^3)	x 35.31	cubic feet
	x 1.31	cubic yard
CAPACITY		
litre (L)	x 0.035	cubic feet
hectolitre (hL)	x 22	gallons
	x 2.5	bushels
WEIGHT		
gram (g)	x 0.04	oz avdp
kilogram (kg)	x 2.2	lb avdp
tonne (t)	x 1.1	short ton
AGRICULTURAL		
litres per hectare (L/ha)	x 0.089	gallons per acre
	x 0.357	quarts per acre
	x 0.71	pints per acre
millilitres per hectare (mL/ha)	x 0.014	fl. oz per acre
tonnes per hectare (t/ha)	x 0.45	tons per acre
kilograms per hectare (kg/ha)	x 0.89	lb per acre
grams per hectare (g/ha)	x 0.014	oz avdp per acre
plants per hectare (plants/ha)	x 0.405	plants per acre

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Contents

Biotechnology and rapeseed breeding: An example of *ex ante* evaluation of research

W.H. Furtan and A. Ulrich[1]

Research expenditures are an investment. This investment, as all investments, is made with the anticipation of a return. The decision as to which activities to pursue through the investment in research demands some sort of cost-benefit analysis.

Most of the economic analysis done on the returns to agricultural research is on an *ex post* basis. This started with the early work of T.W. Schultz, Z. Griliches and V. Ruttan. Ruttan (1982) summarizes the various *ex post* methodologies and gives a detailed account of agricultural research work done in many countries and many commodities. The general conclusion of such *ex post* economic analysis is that there is an underinvestment in agricultural research. Although some have challenged this conclusion on the basis of an underestimation of costs (for example, Fox, 1985), the result remains fairly robust.

However, the use of *ex post* analysis of research does not provide much information to decision makers as to present or future areas of research that have the highest potential payoff. On what basis, or with what criteria, should present agricultural research funds be allocated among competing projects?

The expected economic returns should be one of the more important criteria decision makers use, albeit not the only important criterion (others would include the development of scientists, maintenance of knowledge, and so on).

There has been generally a paucity of research on the economic evaluation of research in an *ex ante* mode, especially relative to those done in an *ex post* mode. A sampling of such *ex ante* research includes Araji, Sim and Gardner (1978), Griffith (1978), Lee (1981) and Shumway (1981). Studies by Klein (1985) and by Ulrich, Furtan and Downey (1984) provide a Canadian context. There is, however, no solid and well-accepted body of literature on this topic, largely because it has never been funded in a consistent manner.

THE PROBLEM

People who allocate contemporary resources to agricultural research are faced with the classic problem of decision making in an uncertain environment. Research expenditures occur many years before any economic benefit is anticipated or realized. In cases where totally new areas of research are being developed, the decision environment may be totally uncertain. What method or methods can be used to assist in making such *ex ante* allocation decisions?

In many cases, the research program may be of a basic research nature where it is impossible to forecast any economic benefits (for example, studying the structure of DNA). In addition, the benefit of one research project may depend upon the success of a number of research projects if any economic benefit is to be realized (for example, the introduction of a new cash crop). Finally, how does one evaluate the benefit of further knowledge that may never get used?

The more applied research projects are, the more straightforward they are in terms of economic evaluation. Many such applied projects are aimed at developing or improving technology used by the industry. In such cases, the impact on output (quantity or quality) or on reduction in input usage can be determined. Once these impacts are estimated, the economic evaluation can proceed.

For instance, applied research on rust resistance in wheat, which increases both the quality and quantity of wheat produced, can be evaluated using the traditional method of cost-benefit analysis. On the other hand, basic research on genetic engineering has little forecastable economic benefit. Although the impact of successful genetic engineering research may be much greater than that of successful applied research, it is much more difficult to evaluate.

An additional problem arises in terms of the mix of public and private benefits flowing from new agricultural research (for example, research into ecological problems of chemical use by farmers has both a public and private component). Economic analysis of the public component is difficult because there may be no market transactions and thus no easily observed price signals. The private market effects are much simpler to handle. New research results may also affect the distribution of income between individual producers through changes in cost of production or market returns. This problem is also difficult to handle because economists do not have any easily quantified means of comparing the relative well-being of individuals (this problem has been totally ignored in the literature on returns to agricultural research).

Notwithstanding these potentially large problems, it is still useful to attempt to develop and to improve methods of *ex ante* economic analysis of research expenditures. Any public expenditure that is large and of continuing nature, such as agricultural research, should be subject to economic evaluation, preferably before the expenditures are made.

With this in mind, this article focuses on one type of *ex ante* evaluation. It describes how a partial equilibrium supply and demand model, *ex post* estimates of previous research results and computer simulations, are used to evaluate the impact of biotechnology on rapeseed production in western Canada.

APPLYING BIOTECHNOLOGY TO RAPESEED BREEDING

In a crop such as rapeseed, biotechnologies may eventually be applied in a variety of ways, from the research station to the farm and the processing plant. At present, many of these possible applications have not been described or perhaps even been thought of.

This article dwells on the possible effect of six biotechniques in developing new rapeseed varieties and on the additional expense that could be justified to develop fully at least two of these biotechnologies for rapeseed breeding purposes. The six newly developing technologies are described below.

Tissue/cell culture refers to a technology that can produce complete plants or masses of similar cells from a few selected cells or plant parts by manipulating the environmental and nutritional surroundings of the selected cells. This in turn greatly lessens the time needed to develop a given new variety, since it speeds up the rate at which a superior variety or plant can reproduce itself.

Anther culture refers to a technology that can regenerate whole plants from haploid cells (male sex cells, which contain only half the typical number of chromosomes). This procedure may produce doubled haploid plants that have only one parent but the normal number of chromosomes. This allows all recessive genes to express themselves in one generation. Thus, plant lines containing undesirable recessive traits can be easily detected and eliminated within one generation instead of in several generations. This in turn greatly lessens the time needed to develop a given new variety.

Embryo rescue techniques enable somewhat unrelated plants to be crossed. Once this happens, the developing embryo is "rescued" from the mother plant before it is rejected and destroyed by the mother plant's tissues. This technique and the following three all have the potential to permit the incorporation or the combining of new desirable traits that would otherwise not be possible.

Somatic cells are cells containing a full complement of chromosomes. When *cell fusion* techniques are used, somatic plant cells are fused together (by removing the cell walls and fusing the two cells and then allowing a new cell wall to form around the fused cell) to form new crosses that would not normally occur.

Cytoplasmic infusion methods incorporate the cytoplasm from the cell of one species into the cell of another species in hopes of successfully affecting cytoplasmic relationships in the host cell, so that previously unattainable crosses can be obtained or cytoplasmically inherited characteristics transferred.

Lastly, and most exotic of all, we have *recombinant DNA technologies*. These technologies involve the genetic engineering of plants by systematically altering the gene and chromosome structures of selected cells. Although in the long run this type of technology may offer the greatest potential for plant improvement, it is at present the least developed and requires the greatest and longest amount of research before it can be used as commonly as, say, the tissue culture technologies.

Relative to rapeseed variety developments, the above-mentioned six technologies can be put into two categories: those that speed up traditional breeding methods, and those that allow new, previously unattainable, genetic recombinations to be made. Tissue/cell and anther culture would fall into the former category while embryo rescue, cell fusion, cytoplasmic infusion and recombinant DNA would fall into the latter category. The following sections outline theoretical models that could be used to estimate the benefits that might accrue from each of these two categories of biotechnology as well as the research costs that might be justified to produce the assumed results.

WAYS TO SPEED UP TRADITIONAL BREEDING

The two techniques that will most immediately speed up traditional rapeseed breeding work are tissue cell culture and the closely related technique of anther culture. Perhaps the biggest difference between these two techniques is that almost any part of a plant can be used in tissue cell culture to regenerate similar cells or whole plants, whereas anther culture restricts itself to using only male sex cells to regenerate similar cells or whole plants.

Normally all cells of a plant contain the same number of chromosomes; however, the exact number of chromosomes varies between plant species. There is one notable exception to this statement: all plant sex cells normally contain exactly half the number of chromosomes contained by other cells in a given plant. When fertilization takes place, the chromosomes from the male and female cells combine into one complete set of chromosomes in the fertilized egg, half coming from the male and half from the female. This fertilized egg then has the capacity to regenerate itself into a new plant, which will exhibit traits that may or may not have been exhibited by its parents.

Each chromosome is made up of smaller units called genes. A gene is usually responsible for one particular trait (for example, narrow leaves). A complete set of chromosomes has two sets of genes governing each trait. The most commonly observed relationship between these two sets of genes is that of dominance or recessiveness. A gene is said to be dominant if, at fertilization, the trait it produces becomes the trait of the fertilized egg cell. A gene is said to be recessive if, at fertilization, the trait it controls is not produced because the gene was combined with a dominant gene for that trait. Thus dominant genes always express themselves in the offspring. Recessive genes, on the other hand, express themselves in the offspring only if, at fertilization, they combine with the same recessive gene from the opposite sex cell. Should they combine with a dominant gene, the recessive genes will be duplicated in the offspring cells but will go undetected in subsequent generations until they combine with a similar recessive gene. When this happens, the recessive trait will once again exhibit itself.

The number of chromosomes and the dominance and recessiveness of varius genes are very important to plant breeders. Firstly, the greater the number of genes, the greater the number of progeny that must be evaluated before a desired strain is obtained (for example, the number of necessary evaluations goes up exponentially with the number of genes under consideration because increasing numbers of permutations and combinations are possible). Secondly, the breeding process is more involved and time-consuming if the desired characteristic is controlled by a recessive gene.

When developing new varieties, plant breeders are very concerned about the possible existence of undesirable recessive genes in a new cross they have developed. To try to eliminate the possibility that unwanted traits may suddenly come to light in future generations, plant breeders usually backcross to the original parents, or self-pollinate their new cross containing one or more improved traits, for six or more generations, and reject any offspring with undesirable traits. It can be shown statistically that such a procedure can virtually eliminate the chance that an undesired recessive gene may unexpectedly crop up after the strain is licensed for farm use.

It usually takes a minimum of 10 years between the time an initial rapeseed cross is made and the time the cross has a commercial impact on the rapeseed industry. Of this 10-year period, at least 3 years are taken up by the Co-op Tests required as part of the licensing procedure. A further year or two is taken up by the seed multiplication necessary before the variety can be adopted widely by farmers. The remaining 5 years are taken up by the initial crossing, selection, reselection and selfing or backcrossing for six to eight generations.

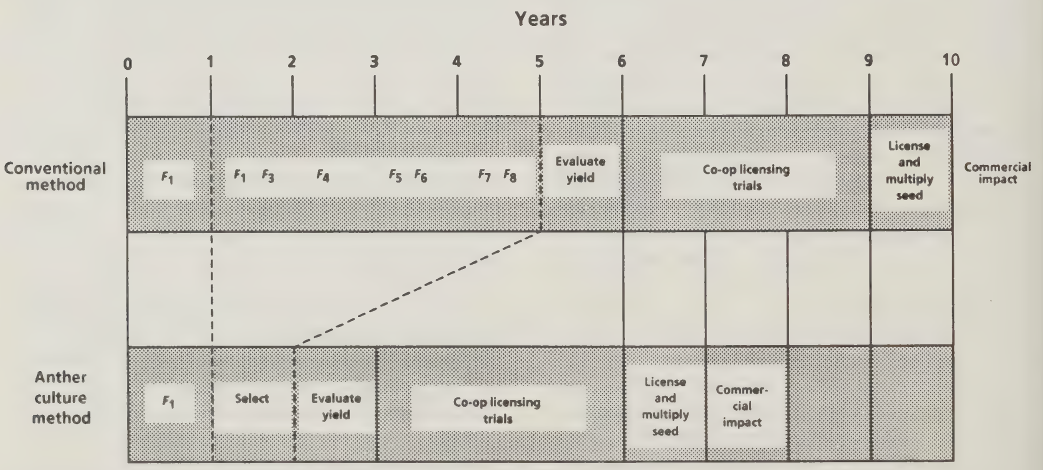
Anther and tissue/cell culture offer a means of significantly shortening the 10-year time span necessary to produce a significant new rapeseed variety. Male sex cells contain only half the normal number of chromosomes. Restoring the normal chromosome number is a necessary step following anther culture and can be done by a series of chemical and environmental shocks and/or treatments that stimulate male sex cells to undergo an abnormal division, which causes a doubling of the chromosome number. In such a doubled haploid cell, each gene is paired with another gene identical to it. This doubled haploid cell is stimulated to develop into a new plant, and the seeds this plant produces are genetically identical to that of the original doubled haploid cell, because it has only one source of genetic information (namely, one male sex cell). In addition, any recessive genes present in the original male sex cell will express themselves in the plant derived from the doubled haploid cell because each recessive gene is paired with itself during the process of producing the original doubled haploid cell.

Because every recessive gene shows up in the first generation when anther culture techniques are used, plant breeders may see, in the first generation, the full genetic potential that exists in a particular rapeseed plant, whether that plant is from a parental strain or the offspring of a cross. This phenomenon allows plant breeders to do away with the traditional six or eight generations of backcrossing or self-pollinating previously needed to guarantee that no undesirable recessive genes still exist in a potential new variety.

Thus, anther culture could reduce the traditional time lag to produce a significant new variety from 10 or 12 years to 7 or 9 years. This is illustrated in Figure 1.

A survey of rapeseed breeders currently using anther culture shows that it is indeed quite possible to save this amount of time. Unfortunately, not enough is yet known about the anther culture technique itself; sometimes it works, but most times it does not. Rapeseed breeders suggest the following three conditions must be met before anther culture can have a significant impact on rapeseed breeding activities: anther culture techniques need to be understood well enough to be standardized (at present, their repeatability cannot be guaranteed), the process of producing doubled haploids needs to be perfected so that its success

FIGURE 1 RELATIVE LENGTHS OF BREEDING PROGRAMS



Note: $F_1, F_2, \ldots F_8$ refer to successive generations of the plant.

rate can be improved, and a technique (mechanical or chemical) needs to be developed that can easily and cheaply identify true "haploids" from "diploids" (that is, to tell the difference easily between haploid cells that have successfully doubled and those that have not).

Simulation of benefits

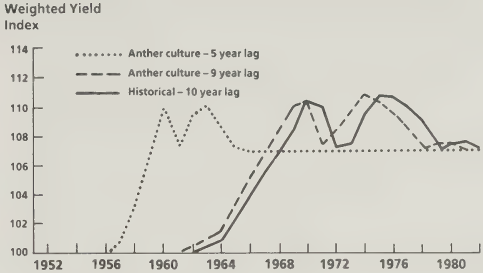
Once these techniques are perfected, the time necessary to produce an improved rapeseed variety will be reduced. The next step is to measure the likely benefits and costs. Unfortunately, such broad issues require many diverse assumptions, including future farm input and output prices, acreage levels, prices and production of other crops, world oilseed production and consumption, and so on. To minimize the number of assumptions required, the issues can be narrowed by posing two specific questions. During the 1951-81 period, what would have been the minimum impact of anther culture if it had been available when the rapeseed breeding program started? During the same period, how much could have been spent to perfect anther culture and still maintain the 51% internal rate of return (IRR) that Ulrich et al (1984) calculate traditional rapeseed breeding has produced?[2]

The 1951-81 period was chosen because it represents the period of time that was used by Ulrich et al (1984) to measure the IRR produced by traditional rapeseed breeding methods. Given the data and formulae described in the first section of Ulrich et al (1984), only slight modifications are necessary to generate answers to the above two questions.

Firstly, it is assumed that the same varieties were released and adopted. Two shortened lag periods are chosen: 9 years and 5 years. The two lag periods are chosen because they represent the extremes of opinions among rapeseed breeders. The most conservative estimate is a 1-year reduction while the most optimistic estimate is a 5-year reduction. The difference between these two scenarios and the historic Weighted Yield Index are shown in Figure 2.

To make the results more conservative, annual historic production levels are held constant (in fact, if rapeseed breeders had been able to release superior varieties faster, increasing numbers of farmers would have found it advantageous to switch wheat and barley acreage to rapeseed and

FIGURE 2 SIMULATED RAPESEED WEIGHTED YIELD IMPROVEMENT INDEX IF ANTHER CULTURE HAD BEEN AVAILABLE, 1951-82



annual historical rapeseed production would probably have increased; however, this assumption is not incorporated in the model).

To make this simulation even more conservative, it is assumed that, even with the use of anther culture, plant breeders would achieve a Weighted Yield Index no higher than that achieved by traditional breeding methods. The net result is a Weighted Yield Index similar to the actual Weighted Yield Index; however, the lag period is shortened by 1 or 5 years.

Justified new research cost levels

One might expect the IRR to rise with the simulated use of anther culture because the period between the time the research expenses are incurred and the time the benefits are realized is shortened. To find out how much could have been spent to perfect anther culture during 1951-81 and still maintain the 51% IRR that traditional rapeseed breeding produced, a subprogram is introduced into the computer simulation of anther culture results. This subprogram calculates the anther culture IRR. If this calculated IRR is higher than 51%, the subprogram increases each annual research cost by 10% and recalculates the IRR. This process is continued until the IRR with the anther culture simulation is reduced to 51%. The results suggest the amount of funds that could have been justifiably spent annually to perfect anther culture for rapeseed breeding in the 1951-81 period or, alternatively, how much could have been spent in a lump sum in 1951 to perfect anther culture (Table 1).

TABLE 1 RETURNS AND "JUSTIFIED" COSTS IN 1971 DOLLARS OF TRADITIONAL AND SIMULATED ANTHER CULTURE RAPESEED YIELD IMPROVEMENT BREEDING, CANADA, 1951-82 ($'000)

	Traditional breeding method		Anther culture method			
	10-year lag		9-year lag		5-year lag	
Year	Costs	Total benefits	Costs	Total benefits[1]	Costs	Total benefits[1]
1951	5	0	6	0	27	0
1952	5	0	6	0	29	0
1953	5	0	6	0	30	0
1954	5	0	6	0	30	0
1955	18	0	21	0	101	0
1956	19	0	22	0	106	5
1957	19	0	23	0	108	82
1958	21	0	25	0	117	482
1959	28	0	34	0	159	536
1960	44	0	53	6	250	642
1961	45	15	54	30	255	1 082
1962	46	33	55	49	262	1 640
1963	51	29	61	87	290	1 004
1964	60	152	72	287	341	1 466
1965	116	485	140	1 178	663	2 059
1966	185	1 716	222	2 355	1 055	3 000
1967	228	2 665	274	3 053	1 300	3 395
1968	247	1 181	296	2 952	1 406	2 425
1969	265	2 127	318	2 614	1 510	1 747
1970	410	5 477	492	5 153	2 336	3 661
1971	430	11 164	516	3 932	2 452	7 932
1972	467	9 312	561	9 446	2 663	9 312
1973	152	7 851	183	10 667	869	7 740
1974	152	10 139	183	11 223	869	7 357
1975	152	19 239	183	18 122	869	12 612
1976	152	18 051	183	17 313	869	12 562
1977	152	9 140	183	7 976	869	6 632
1978	152	18 194	183	15 345	869	15 127
1979	152	24 884	183	25 592	869	24 530
1980	152	21 905	183	21 602	869	20 997
1981	152	14 399	183	13 898	869	13 989
1982	152	9 235	183	9 235	869	9 235
1982-2002 (projected average)	152	15 146	183	14 912	869	14 710

[1] Under the anther culture scenarios, total benefits are less than under the traditional because of the assumption that annual production under all scenarios is constant. Thus, in the early years of the anther culture scenarios, the improved varieties are used to produce lower levels of rapeseed production because their simulated date of release corresponds to a time when levels of rapeseed production was at lower than average. In spite of this, the earlier occurrence of benefits under the anther culture scenarios is large enough to raise the IRR sufficiently to justify much higher research costs.

Source: Authors' calculations.

These simulated results show that the perfection of anther culture techniques for rapeseed breeding would have dramatically affected the IRR of rapeseed breeding, had it been available in the 1951-81 period, even under extremely conservative assumptions. Consequently, reducing the research lag period by 1 year would justify spending an additional 20% of the annual research budget to perfect anther culture.

These results become even more dramatic when the lag period is reduced to 5 years. With

this simulation, an increase of 570% of the annual research budgets would be justified to perfect anther culture. To bring home the size of this justifiable increase, the reader is reminded that in 1983 about $2.5 million (in constant 1983 dollars) was spent on rapeseed breeding. The simulation results indicate that this amount could have been increased to $14.3 million, with $11.8 million spent solely on perfecting anther culture in 1983 alone! The reader is further reminded that these results are based on extremely conservative assumptions about how the simulated anther culture results differ from traditional breeding methods. In addition, they are based on the requirement that the simulated anther culture IRR must be at least as high as that obtained with traditional breeding methods.

NONTRADITIONAL BREEDING

At least four known techniques allow rapeseed breeders to do things they could never do using only traditional breeding methods. In traditional breeding work, scientists can only cross *Brassica* species that are very closely related to rapeseed. Because of this, there is fairly limited potential for improvement in many rapeseed traits. However, the new biotechnology being developed will allow crosses to be made between quite unrelated genera and species, and will allow plant breeders actually to alter the genetic makeup of a rapeseed plant without crossing to anything, by artificially altering the internal structure of individual genes. Cell fusion, cytoplasmic infusion and embryo rescue techniques fall into the former category, and recombinant DNA techniques fall into the latter category.

The potential benefits that such new technologies will ultimately generate in the rapeseed breeding field are much harder to determine than the techniques that simply speed up traditional breeding methods. Part of this difficulty lies in the fact that these techniques are a great deal less developed than anther or tissue/cell culture. This is especially true of recombinant DNA techniques, which have the greatest potential to improve rapeseed varieties in the long run.

At present, the best we can do is to describe a few of the developments that might be possible using nontraditional breeding methods. Certain species of the *Brassica* family have quite hairy leaves (mustard, for example) quite unlike existing rapeseed, and hairy leaves tend to minimize insect problems, possibly because the hairs on the leaves make it difficult for insects to feed on these plants. If this is true, rapeseed with hairy leaves would probably have few insect pests. However, traditional breeding techniques do not allow the introduction of hairy leaves into new crosses of rapeseed, because no very closely related species has hairy leaves. Nontraditional breeding methods would make such a development possible.

Rapeseed requires high levels of nitrogen to produce high yields. Normally this nitrogen must be supplied from an outside source such as fertilizer. Legumes, on the other hand, act as hosts for certain bacteria which convert nitrogen from the air into plant-usable nitrogen. This almost totally eliminates the need for fertilizer-supplied nitrogen. Using traditional breeding techniques, it is impossible to transfer the nitrogen-fixing ability of legumes to rapeseed. On the other hand, nontraditional breeding techniques may allow such a dramatic breakthrough to take place.

The development of hybrid corn, sorghum and sunflowers had a dramatic effect on the yield potential of these crops. Rapeseed breeders tried without success to produce hybrid rapeseed using traditional breeding methods. However, the application of several of the nonconventional techniques mentioned above have the possibility of producing a rapeseed hybrid with a potential yield almost 40% higher than the best of the conventionally bred varieties.

The above-mentioned possible improvements to rapeseed with the use of nonconventional breeding techniques sound a little like science fiction (and these are only three of the many possibilities). How can one estimate the costs that could be justified to ensure that these results are indeed possible in the not-too-distant future? One might conclude that, if anything, the development of nontraditional breeding methods will be even more valuable than the development of the previously described anther and tissue/cell culture techniques. Consequently, the research costs that could be justified to perfect these technologies for rapeseed breeding would be even higher than the costs that could be justified to perfect anther and tissue/cell culture.

With this in mind, we propose a simulation similar to that for anther culture. However, only one possible outcome of the nonconventional breeding techniques is simulated in it, because one should be sufficient to illustrate the

approximate size of additional research expenditures that might be justified and because only one major result has so far been produced with nonconventional techniques.

Simulation of benefits

The use of nonconventional breeding techniques already demonstrates that a rapeseed hybrid with a yield approximately 40% higher in test plots than the best conventionally bred variety is commercially possible. What value, at the minimum, would this have had, if hybrid rapeseed technology had been available in the 1951-81 period? How much could have been justifiably spent to perfect such a technology during 1951-81 and still maintain the 51% IRR that traditional rapeseed breeding produced?

To come up with very approximate answers to these questions, two simulations are carried out in the same manner and with the same data as previously described (historic production levels are held constant). However, the Weighted Yield Index is modified to show the effect of a 30% yield improvement combined, first, with the traditional Weighted Yield Index pattern and, second, with the use of anther culture to reduce the lag period by 5 years,[3] along with a relaxation of the assumption that plant breeders using these two techniques would reach a "potential yield plateau" equal to the level reached in 1981 by traditional breeding efforts. These two Weighted Yield Index scenarios are illustrated in Figure 3; they are used because they represent the pessimistic and the optimistic view of the possible

FIGURE 3 SIMULATED RAPESEED WEIGHTED YIELD IMPROVEMENT INDEX IF HYBRID TECHNIQUES HAD BEEN AVAILABLE, 1951-82

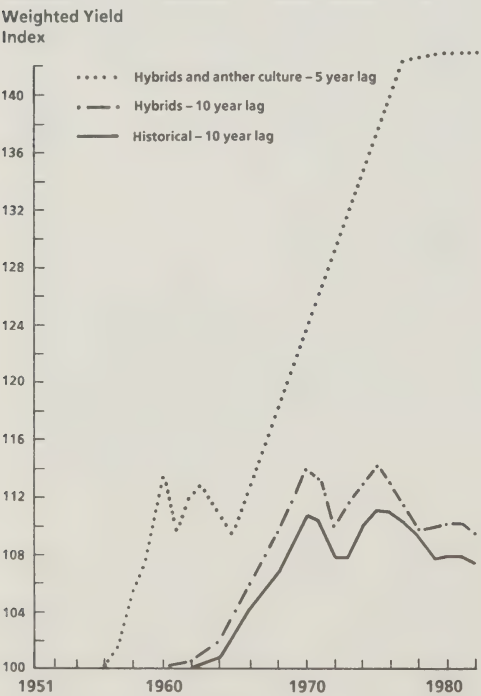


TABLE 2 RETURNS AND "JUSTIFIED" COSTS IN 1971 DOLLARS UNDER TWO HYBRID RAPESEED YIELD SIMULATIONS OF 30% YIELD IMPROVEMENT, CANADA, 1951-82 ($'000)[1]

	10-year research lag		5-year research lag	
Year	Costs	Total benefits	Costs	Total benefits
1951	6	0	42	0
1952	7	0	45	0
1953	7	0	47	0
1954	7	0	47	0
1955	23	0	160	0
1956	24	0	167	6
1957	25	0	171	105
1958	27	0	185	629
1959	36	0	251	702
1960	57	0	395	844
1961	58	19	403	1 416
1962	60	43	413	2 155
1963	66	38	459	1 319
1964	78	197	539	1 922
1965	151	631	1 047	2 696
1966	241	2 239	1 665	5 138
1967	297	3 483	2 053	7 214
1968	321	2 853	2 219	6 176
1969	344	2 790	2 384	5 204
1970	533	7 201	3 689	12 527
1971	559	14 667	3 871	30 747
1972	607	12 191	4 204	40 454
1973	198	10 281	1 372	37 355
1974	198	13 317	1 372	39 165
1975	198	25 303	1 372	73 615
1976	198	23 722	1 372	80 006
1977	198	12 005	1 372	45 894
1978	198	23 861	1 372	104 683
1979	198	32 583	1 372	169 683
1980	198	28 690	1 372	145 301
1981	198	18 725	1 372	96 176
1982	198	12 091	1 372	63 907
1983-2002 (projected average)	198	19 835	1 372	101 795

[1] For a comparison of costs and returns with traditional breeding techniques, see Table 1.

Source: Authors' calculations.

effect hybrids would have had on the movement of the traditional Weighted Yield Index, if they had been possible in the 1951-81 period.

The total net benefits generated by these two scenarios are shown in Table 2.

Justified new research cost levels

Under the first hybrid scenario, the Weighted Yield Index is increased by 30%, but the traditional lag period of 10 years is not altered. This simulation shows that, if this scenario had taken place, research costs could have been increased by 30% annually, and a 51% IRR would still have been maintained. This result makes sense because, if benefits were simply increased by 30%, costs could likewise be increased by 30%,and the IRR would remain constant.

Under the second hybrid scenario, the lag period of the Weighted Annual Index is decreased to 5 years and the size of the annual index is increased by 30% to simulate the combined effects of anther culture and the release of hybrids. The simulation shows that, if this scenario had taken place, research costs could have been increased by 900% annually, and a 51% IRR would still have been maintained. This huge increase in costs is justified not only because the stream of benefits is larger but also because it comes on stream sooner (this in turn illustrates how the combined effect of two research discoveries can produce benefits far in excess of what each discovery could produce by itself).

CONCLUSIONS

The article outlines a method in which a partial supply and demand model, *ex post* analysis and computer simulations can be combined to evaluate the future impact of certain types of research in an *ex ante* mode. The example used in this study shows a high potential return to biotechnology research in rapeseed. A considerable quantity of funds could be committed to this area of research before the rate of return would go below 50%.

This *ex ante* evolution contains useful information for research decision makers. If all major project areas are evaluated in this manner, present-day decision makers will be better able to allocate research resources to contemporary research projects.

APPENDIX

To calculate the IRR achieved by Canada's conventional rapeseed breeding program since 1951, Ulrich et al (1984) use what is often referred to as the Index Number Approach combined with the concepts of consumers' and producers' surpluses. A brief description is given here for the benefit of readers not familiar with these techniques.

Evaluation of past yield improvements

When calculating the increase in yields due solely to new, higher-yielding varieties, one cannot simply look at the rise in the average yield of Canadian rapeseed over a number of years. This is because, in addition to using newer varieties, farmers are using progressively larger amounts of fertilizers, better chemicals, better harvesting methods and generally better management techniques. All of these contribute to higher yields.

To separate and isolate the production increases due solely to higher-yielding varieties, one must work backward from research station yield trials. Before a new variety is licensed, it must be grown in test plots at 20 or 30 locations across western Canada for 3 years. The yield of the potential new variety is compared with existing licensed varieties at all the test locations over a minimum of 3 years. Only then may the potential new variety be licensed, if it has shown itself to be superior to existing varieties in at least one aspect (higher quality, higher yield or greater disease resistance).

Since 1950, at least 20 rapeseed varieties have been licensed in Canada. These are shown in Table A.1 along with their relative yielding abilities. The yielding ability is expressed as a percentage of the original *B. napus* and *B. campestris* varieties that were introduced in the 1940s. For example, Westar is given a yield index of 124. This means that, on the average, Westar yields 24% more than the original *B. napus* variety called Argentine. Table A.1 also shows how yield is generally depressed when varieties with higher-quality attributes are introduced (however, lower-yielding varieties may also have been licensed if they exhibit improved traits such as earlier maturity or greater disease resistance).

TABLE A.1 ESTIMATED DISTRIBUTION (%) OF ACRES SOWN TO RAPESEED BY VARIETY, WESTERN CANADA, 1960-83

Year	Yield index	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971
B. napus varieties													
Argentine (1943)	100	10.0	8.0	6.0	4.0	2.0							
Golden (1954)	101	15.0	17.0	17.0	16.0	5.0	3.0	2.0	2.0	0.2			
Nugget (1961)	100			2.0	5.0	5.0	4.0	3.0	2.0	2.0	1.0		
Tanka (1963)	105					13.0	18.0	20.0	13.0	4.9	3.0	1.0	
Target (1963)	110								8.0	11.0	20.0	23.0	5.0
Oro (1968)	106									1.0	1.0	1.0	24.0
Turret (1970)	113												1.0
Zepher (1971)	106												
Midas (1973)	115												
Tower (1974)	106												
Regent (1977)	110												
Altex (1978)	112												
Andor (1981)	117												
Westar (1982)	124												
Other	106												
Total *B. napus*		25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	19.1	25.0	25.0	30.0
B. campestris varieties													
Polish (1943)	100	60.0	55.0	45.0	30.0	25.0	20.0	15.0	15.0	16.3	8.0	2.0	
Arlo (1958)	101	15.0	20.0	30.0	45.0	50.0	50.0	35.0	25.0	22.0	12.0	3.0	
Echo (1964)	112						5.0	25.0	35.0	42.6	55.0	69.0	64.0
Polar (1969)	109											1.0	2.0
Span (1971)	107												4.0
Torch (1973)	111												
Candle (1977)	101												
Tobin (1981)	108												
Other	106												
Total *B. campestris*		75.0	75.0	75.0	75.0	75.0	75.0	75.0	75.0	80.9	75.0	75.0	70.0
Product		10 030	10 037	10 047	10 061	10 120	10 203	10 437	10 592	10 674	10 893	11 081	11 021
Weighted Yield Index		100.0	100.1	100.2	100.3	100.9	101.7	104.1	105.6	106.4	108.6	110.5	109.9

(Continued)

TABLE A.1 ESTIMATED DISTRIBUTION (%) OF ACRES SOWN TO RAPESEED BY VARIETY, WESTERN CANADA, 1960-83 (CONCLUDED)

Year	Yield Index	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
B. napus varieties													
Argentine (1943)	100												
Golden (1954)	101												
Nugget (1961)	100												
Tanka (1963)	105												
Target (1963)	110	1.7	2.1	1.0	0.9	0.8							
Oro (1968)	106	6.5	4.0	2.4	1.2	0.5	0.1	0.3					
Turret (1970)	113	0.1											
Zepher (1971)	106	27.9	19.8	5.7	1.7	0.8	0.5	0.2					
Midas (1973)	115		1.3	20.0	30.2	23.2	20.5	16.3	6.2	3.0	1.6	1.1	
Tower (1974)	106			1.9	11.9	24.1	31.0	31.8	20.7	13.9	8.8	5.0	2.6
Regent (1977)	110							1.1	20.3	25.2	27.0	28.3	18.8
Altex (1978)	112								0.8	14.3	21.5	23.2	12.6
Andor (1981)	117												12.9
Westar (1982)	124												
Other	106						0.5	0.8	0.8	0.8	1.1	1.0	0.8
Total *B. napus*		36.2	27.2	31.0	45.9	49.4	52.6	50.5	48.8	57.2	60.0	58.6	47.6
B. campestris varieties													
Polish (1943)	100												
Arlo (1958)	101												
Echo (1964)	112	13.3	11.0	52.0	2.0	0.8							
Polar (1969)	109	1.8	1.0										
Span (1971)	107	48.7	60.2	32.2	10.1	6.7	2.3	1.1	0.4	0.5			
Torch (1973)	111		0.6	31.6	42.0	43.1	43.7	36.1	24.7	15.2	9.2	7.0	3.3
Candle (1977)	101						0.9	11.6	25.3	26.3	29.8	33.5	16.3
Tobin (1981)	108												32.0
Other	106						0.5	0.7	0.8	0.8	1.0	0.9	0.8
Total *B. campestris*		63.8	72.8	69.0	54.1	50.6	47.4	49.5	51.2	42.8	40.0	41.4	52.4
Product		10 741	10 752	11 005	11 108	11 039	11 007	10 885	10 749	10 768	10 762	10 742	10 901
Weighted Yield Index		107.1	107.2	109.7	110.7	110.1	109.7	108.5	107.2	107.4	107.3	107.1	108.7

Sources: 1960-71, based on estimates by K. Downey and A.J. Klassen, Agriculture Canada.
1972-83, based on data supplied by the three provincial wheat pools.

When estimating the production increases due to the planting of better varieties, one must also take into account the percentage of total rapeseed acreage planted to each improved variety in each year. For instance, a variety may yield 10% more than a base variety, but it may have poor straw strength. If it has poor straw strength, farmers may not plant it, in spite of its supposed yield advantage, because its poor straw strength makes it very difficult to harvest.

Thus, in addition to collecting data on the test station yield of different varieties, one must collect data on the percentage of total rapeseed acreage that is planted to each of the different rapeseed varieties. Fortunately, this type of data is collected annually by several of the Prairie grain companies. Table A.1 presents these data for the years 1960 to 1983.With data on the relative yield advantage of different varieties and the percentage of total acreage seeded to each variety in each year, the theoretical increase in annual production due to the development and use of improved rapeseed varieties can be calculated by multiplying the relative yield index of each variety by the percentage planted of each variety in question. Adding up the products of this computation for all the varieties grown in a given year produces the totals found in the row labeled "Product" in Table A.1.

Once these annual products have been computed, the annual weighted yield improvement that has taken place can be calculated by dividing the annual product by the product in 1960. This will show how much production has increased on a percentage basis because higher-yielding varieties of rapeseed were developed and grown (for example, in Table A.1 in 1983 the Weighted Yield Index was 108.7, indicating that the new varieties grown in 1983 increased total rapeseed production in 1983 by 8.7% over and above what it would have been if the 1960 combination of varieties had been planted).

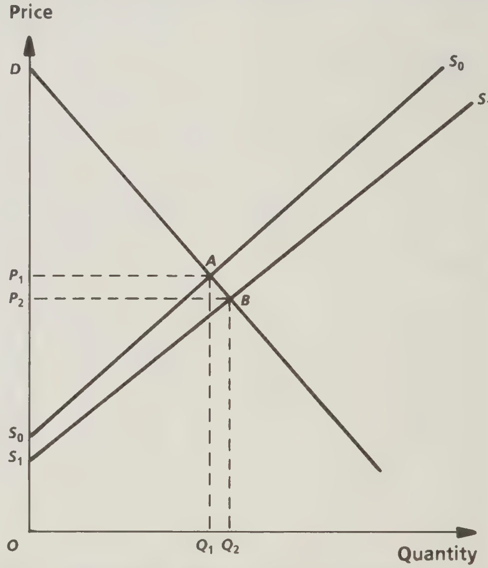
Benefits of higher yields

Over the years, economists have developed several methods to estimate the value of higher-yielding varieties. One of the most accepted and easily understood methods is referred to as the economic surplus or consumer/producer surplus approach.

A supply curve shows the quantity of a commodity that producers are willing to supply at different price levels. If producers are given something that allows them to lower their unit cost of production, they will be willing to supply a greater quantity than previously at every given price level.

Graphically such an event is represented by a shift in the supply curve downward and to the right (in Figure A.1, the supply curve shifts from S_0S_0 to S_1S_1). For example, production of 1000 bushels may have originally cost $4000. A higher-yielding rapeseed variety may allow 1200 bushels to be produced for the same $4000 expenditure. Alternatively, the $4.00 cost of producing one bushel using the old variety can be reduced to $3.33 (4000 ÷ 1200) per bushel of the new variety.

FIGURE A.1 THE EFFECT OF A HIGHER-YIELDING VARIETY ON A SUPPLY CURVE



Note: $F_1, F_2, \ldots F_8$ refer to successive generations of the plant.

When the man in the street is asked what effect a higher-yielding variety is likely to have, he will probably reply that it should lead to lower food costs so that consumers would be better off. On the other hand, lower prices mean that farmers have to sell more units to be as well off as they were before. Such intuitive feelings can be illustrated using the concept of consumers' and producers' surpluses.

In Figure A.1, the supply curve is shifted downward and to the left when a higher-yielding variety is introduced. Before the introduction of the new variety, consumers' surplus is the area DAP_1. After the new variety is introduced, consumers' surplus is area DBP_2. Clearly, consumers have gained because they can buy a larger quantity at a lower price. The size of this gain is represented by area P_1ABP_2.

Before the new variety is introduced, producers' surplus is area P_1AS_0; after the new variety is introduced producers' surplus is area P_2BS_1. Producers will be better off with the new variety only if area P_2BS_1 is greater than area P_1AS_0 (this in turn depends on the relative elasticities of the supply and demand curves). The net change in producers' surplus is thus the difference between area P_2BS_1 and P_1AS_0.

The total first-round benefits of a new higher-yielding variety can be found by adding the change in consumers' surplus with the change in producers' surplus (area P_1ABP_2 + area P_2BS_1 - area P_1AS_0). To calculate these benefits over a number of years, we need an estimate of how much the supply curve shifts downward each year (this is obtained from the Weighted Yield Index calculated in Table A.1), annual prices for P_2, annual quantities for Q_2, an estimate of where S_1 is in relation to P_1 and estimates of the demand and supply elasticities. Once these data are obtained, the following formulae, developed by Rose (1980), can be used to calculate the monetary value of the annual consumers' and producers' surpluses generated by the planting of higher-yielding varieties:

$$P_1 = P_2/[1 - (K^*e)/(e + n)] \quad (1)$$
$$Q_1 = Q_2/[1 + (K^*e^*n)/(e + n)] \quad (2)$$
$$TS = .5^*Q_1[K^*P_1 + (S_1\text{-}S_2)] + .5^*K^*P_1(Q_2\text{-}Q_1) \quad (3)$$
$$CS = Q_1(P_1\text{-}P_2) + .5(P_1\text{-}P_2)^*(Q_2\text{-}Q_1) \quad (4)$$
$$PS = TS - CS \quad (5)$$

In these equations

K = (Weighted Yield Index - 100)/100;
e = price elasticity of supply;
n = price elasticity of demand;
P_2 = postadoption price;
Q_2 = postadoption quantity;
P_1 = preadoption price;
Q_1 = preadoption quantity;
S_2 = postadoption intercept term;
S_1 = preadoption intercept term;
TS = total net producers' plus consumer's surplus;
CS = net consumers' surplus; and
PS = net producers' surplus.

Combining annual rapeseed quantity and price data, elasticity estimates from other rapeseed studies, the Weighted Yield Index from Table A.1, and the estimate that $S_1 = .3^*P_1$ with equations (1), (2), (3), (4) and (5) yields the estimated total net monetary value of consumers' and producers' surpluses. These are shown in Table 1 under the heading "Total benefits, traditional breeding method."

The research time lag

Rapeseed breeding is a long-term investment. Between the time the initial cross is made and the time the variety arising from the cross has a measurable impact on rapeseed production, 10 or more years may have passed. The recently released variety Westar is a fairly typical example. The original cross that eventually resulted in Westar was made in 1974. However, its first significant impact came in 1984. This is why Ulrich et al (1984) assumes that the surpluses produced since 1961 using traditional breeding methods are the result of research investments made 10 years earlier.

Research costs

Table 1 illustrates the fairly substantial benefits that have been produced annually from the development and adoption of higher-yielding varieties. However, we have no way of knowing whether this is a high return on investment unless we look at the funds spent to develop these varieties.

In the case of rapeseed breeding, the time lag between the initial investment and the first commercial effect of this expenditure is about 10 years. Thus, to evaluate the flow of benefits from 1961 onward, we must consider the expenses incurred from 1951 onward.

Because rapeseed research has been performed in many different research institutions, no one institution has data on the total annual cost of the Canadian rapeseed breeding program. To overcome this problem, a survey of old research institution records approximates the annual number of professional person-years of work devoted to rapeseed breeding work. In addition,

estimates of the annual cost of a professional person-year of research are available, particularly those of Zentner (1982). Then, annual person-years of professional research can be multiplied by the annual estimated cost of a person-year of research to obtain an estimate of the total annual expenditure on rapeseed breeding work. The results of these calculations are shown in Table 1 under the heading "Costs, traditional breeding method."

The rate of return from higher-yielding varieties

Once a stream of costs and benefits from an investment is known, we can calculate the profitability of the investment in a number of ways. This can take the form of calculating a benefit/cost ratio, net present value, or external and internal rate of return. Each of these measures of profitability has its own strengths and weaknesses. For the purposes of this study, however, the internal rate of return (IRR) is taken as the most appropriate measure of profitability.

The IRR can be thought of as the maximum rate of interest that could be paid if all the costs had to be financed with loans. If the interest rate was higher than the IRR, the interest on the loan could not be paid off within the time period under study.

Before we can calculate an IRR, we must determine the time period under study and bring all costs and benefits to "constant" (inflation-adjusted) dollars. Once this is done, a computer program can try progressively higher interest rates until, at last, the benefits can no longer pay the interest. In mathematical terms, the IRR is calculated as follows:

$$\sum_{t=0}^{T} \frac{I_t}{(1+r_1)^t} = \sum_{t=0}^{T} \frac{B_t}{(1+r_1)^t} \qquad (6)$$

where

r_1 = the internal rate of return (IRR);
B_t = the net benefit in year t;
I_t = the net investment cost in year t; and
T = the year in which the research ceases to produce benefits

Ulrich et al (1984) assume that the period under review would be from 1951 to 2002, a period of 51 years.[4] They assume that benefits began in 1961 and will continue until 2002 (actual benefits, however, could be calculated only up to 1982; for the remaining 30-year period, it is assumed that annual benefits will at least be the average of the inflation-adjusted benefits enjoyed in 1980, 1981 and 1982). Costs are assumed to begin in 1951 and to continue to 2002 (however, after 1971, it is assumed that costs are 35% of the average inflation-adjusted costs in 1969, 1970 and 1971, because the benefits of research work after 1982 cannot be accurately measured, since research conducted after 1971 has not yet produced commercial results; the 35% figure is used because it is the upper-limit estimate made by plant breeders as to the cost of maintenance research that might be required just to maintain the present Weighted Yield Index for the next 30 years until 2002).

The net results of all these calculations are shown in two columns in Table 1 under the heading "Traditional breeding method." The IRR is calculated to be 51%. The reader should recall that this IRR has been adjusted for inflation and so is a very high rate of return. For example, when the inflation rate is 6% and savings accounts pay 9%, the real rate of interest, comparable to the IRR, is only 3%.

NOTES

[1] W. Hartley Furtan is a professor of Agricultural economics at the University of Saskatchewan at Saskatoon. Alvin Ulrich is a research assistant in agricultural economics at the University of Saskatchewan at Saskatoon.

[2] The appendix of this article gives a brief outline of how Ulrich et al (1984) calculate this IRR for traditional rapeseed breeding.

[3] Although several hybrids tested to date showed a 40% yield improvement, they were produced using hand-crossed seed and grown only in test plots. For this reason, it is likely that large-scale commercial use of such hybrids may generate only a 30% yield improvement. In addition, some of the increased farmers' revenue from yield increases greater than 30% would be spent on the increased cost of hybrid seed compared with conventional seed.

[4] Agriculture research has a long lag effect. The benefit and maintenance research costs are considered to extend another 20 years after 1982 because there is usually nothing to stop farmers from continuing to plant the best varieties from 1982 for another 20 years as long as a little yield maintenance research continues to be carried out.

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Evaluation of the crop production development research program

P.J. Finn[1]

INTRODUCTION

The Program Evaluation Division of Agriculture Canada in 1984-85 carried out an evaluation of the department's Crop Production Development Research (CPDR) program. This article reviews the analysis of the economic impacts and effects of past program expenditures conducted in support of that evaluation.

The purpose of program evaluation in the federal government is to assist in ensuring that deputy heads of departments and agencies have the appropriate information on program results in order to be able to make more informed decisions on the management and resourcing of their programs, to be accountable for the programs (and for public monies) for which they are responsible, and to provide quality advice to ministers.[2]

The evaluation function is a key element of the federal government's Policy and Expenditure Management System (PEMS) and the allocation of government resources by envelopes. A prime feature of the new resource envelope system is that cabinet policy decisions guide cabinet expenditure decisions. As a key instrument in this process, program evaluation provides essential feedback to strategic planning and other management processes forming part of the PEMS. This article explains the CPDR program, outlines the results of the program effectiveness analysis, and summarizes its findings.

THE CROP PRODUCTION DEVELOPMENT RESEARCH PROGRAM

The Crop Production Development Research (CPDR) program includes production research on wheat and other cereal crops, oilseeds, forages, horticultural crops, and field crops.

Crop production research is directed toward improving the efficiency of production and quality of crops to meet current and anticipated market demands through the development of new varieties with higher yields, greater resistance to pests and increased tolerance to extreme environmental conditions. The research program encompasses a broad spectrum of research activities: basic research, applied research, maintenance research and experimental (technology) development.

Basic research includes the development of biotechnological breeding techniques such as haploiding,[3] as well as more general work on plant physiology and metabolic processes. Applied research includes varietal improvement directed toward the identification and development of specific characteristics such as rust resistance or increased protein content. Experimental development includes the more straightforward selection and crossing of lines with known characteristics from a given population. The development of improved production techniques and cultural practices also falls into the category of experimental development.

The bulk of program activity, varietal development, falls into the categories of applied research and experimental development. Maintenance research, that is, research applied to the problem of assuring the continuation of research benefits, such as reducing constraints on the use of crop innovations or the maintenance and improvement of pest resistance properties in the face of constantly evolving pests, also lies within the applied range of the research spectrum. Such research may actually be more necessary for crop improvement work than for some other types of innovation.[4]

ECONOMIC ANALYSIS OF PAST PROGRAM EFFECTIVENESS

Four categories of program effectiveness measures were developed to assess the program's past objective achievement and its impacts and effects, including net societal benefits, the impact on regional economic growth, the impact on Canada's international trade position, and impacts on marginal land utilization.

This effectiveness analysis was conducted only for wheat, barley, rapeseed and forages. It

focused on the societal benefits attributable to improved yields from the introduction of new varieties, although the programs often generated other benefits whose effects are difficult to estimate with any degree of precision. Program objectives also included disease prevention, but it was impossible to construct plausible and nontrivial economic scenarios of the consequences of such efforts.

While some 44% of the CPDR budget in 1983-84 was directed to improvements in horticultural crops, it was not possible to carry out any kind of effectiveness analysis of past research activities for any of these crops. This was mainly because data bases were not adequate to conduct retrospective impact analysis. In the case of some major horticultural crops (apples and grapes, for example), few if any of the varietal improvements occurred during the 1970s, nor could they be attributed exclusively to Canadian scientific efforts. In the case of potatoes, new varieties introduced during 1972-83 accounted for only about 4% of the value of domestic production in 1983, with about 3% attributable to the CPDR program. Also, there were no significant yield improvements in new over old varieties. Data base limitations and attribution problems also prevented any estimation of the *ex post* net societal benefits from introducing new varieties of other grain and oilseed crops such as corn and soybeans.

Because of the continuous interaction between federal crop research efforts and those of the provinces, universities and industry, most of the impact analyses did not distinguish between Agriculture Canada CPDR activities and those of the other actors. The exception was the "international trade effects" analysis, where CPDR impacts were estimated.

Net societal benefits of the program

This analysis examined the net societal benefits achieved in Canada from past public investment in crop research for selected commodities, namely, wheat, barley, rapeseed and forages (see Furtan and Ulrich, 1985).

Method of analysis

Benefit/cost analysis and consumer/producer surplus analysis were employed to estimate the rate of return over the 1961-2003 period from crop production development research for wheat, barley and rapeseed and over the 1967-2013 period for forages. The research costs were borne by federal and provincial governments and by industry over the 1950-73 period, with subsequent maintenance research costs estimated to continue until 2003. The net benefits were apportioned among domestic and foreign consumers and among domestic producers, including primary producers and the other component industries of the food chain. It was assumed that foreign producers did not benefit from Canadian research in these crops.[5]

Econometrics was employed to estimate the marginal benefits of additional research expenditure on these four crops.

This methodological approach required accurate modeling and estimation of seven critical variables. The supply and demand schedules for each crop marketed during the period of the revenue stream was determined. The lags between the contribution of research effort and the subsequent results for the four crops was selected to be 10 years under the advice of expert crop scientists for all crops, with the exception of forages, for which the lag was extended to 17 years, due to the longer research time usually required on that crop before results occur. The amounts by which the crop breeding research shifted the corresponding supply curves was determined. Hypothetical supply curves were developed to approximate those that would have existed had farmers used only unimproved (old) varieties in existence before the benefit stream was assumed to commence (1961 for most crops and 1971 for forages). The elasticities of demand and supply over the benefit period were determined, as these influenced directly the distribution of the returns between producers and consumers. The federal, provincial and industry annual research costs for the 1951-73 period (1954-66 in the case of forages) comprised the wages of scientists and capital (nonwage) expenses; annual maintenance research costs for 1974-2003 (1967-2013 in the case of forages) were estimated to equal one-third of those of the initial period.[6] The proportions of total crop breeding research costs to be assigned to these individual crops was determined under the advice of expert crop research scientists. And the opportunity cost of capital selected for discounting the benefit and cost streams to present values and for calculating the benefit/cost ratios and net present values was set at a real interest rate of 5%. The annual benefits were extended over the 1984 - 2003 period (1984-2013 for forages) and were

assumed to be equal to the average of the real/dollar equivalent of the benefits 1981, 1982 and 1983.

Data on the relative average yield advantage of new (post-1960) over old varieties,[7] obtained from a series of annual variety trials for wheat, barley, rapeseed[8] and forage based on yields in various plot tests in different geographical regions of the Prairies and from the percentage of total acreage seeded to each variety in each year, were used to derive indices of increases in annual production (weighted by variety), relative to hypothetical base period indices for wheat, barley, rapeseed and forages. This was obtained by multiplying the relative average yield index of each variety in each annual trial by the percentage of area planted to each variety in question for each crop. By adding up the products of these computations for varieties grown in a given year, a "weighted variety production index" was derived for each year.

Annual variety yield improvement indices were then calculated for each crop by dividing the variety production index for each year during the period 1961-83 (1971-83 for forages) by the variety production index in the base year (1960) and by multiplying by 100.

Since the relative yield index of each new or old variety was the average of a sequence of annual performance trials, the influence of weather patterns as a potential explanatory variable of the yield differentials between new and old varieties was therefore isolated to some degree. The effect of trends in input quantities (and input costs) on yields was also largely isolated in the variety trials as a potential explanatory variable. These were always carried out under best-practice (summerfallow) conditions in all the major growing areas, thus minimizing the requirements for chemical inputs and also assuring a degree of relative constancy in the agricultural inputs and their costs from year to year.

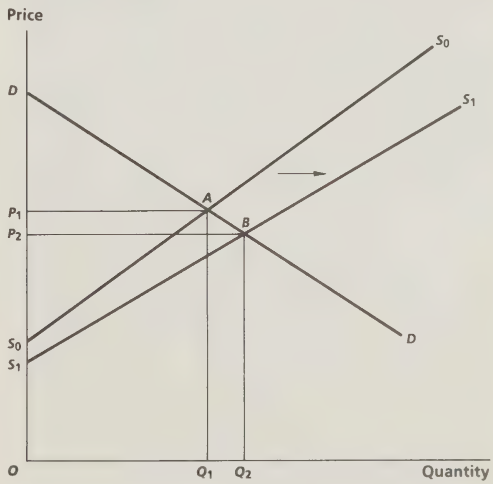
The consumer/producer surplus, benefit/cost analytical model

The consumer-producer surplus model[9] employed in this analysis is briefly described in the figure. The supply curve of the crop has shifted downward and to the right because a higher-yielding variety has been introduced.[10] The consumers' surplus before the introduction of the new variety is the area DAP_1. The consumers' surplus after the introduction of the new variety becomes the area DBP_2. Clearly, consumers have gained because they can buy a larger quantity at a lower price. The size of this gain is represented by area P_1ABP_2.

The total first-round societal benefits of a new, higher-yielding variety can be found by adding the change in consumers' surplus (area P_1ABP_2) to the change in producers' surplus (area P_2BS_1 – area P_1AS_0). The increase in consumer and producer surplus (net societal gains), which is calculated from the shift in the supply curve due to crop breeding research, is used to develop benefit estimates used in the calculation of the performance indicators, namely, benefit/cost ratios, net present values and internal rates of return, for past research expenditure on these four crops.

Econometrics (quadratic functional form-regression analysis) is used to obtain estimates of the value of the marginal productivity of research, which is measured by the change in total consumer-producer surplus caused by additional research expenditures. The mean level of research investment over the estimation period is one of the independent variables against which the estimated annual

FIGURE 1 THE EFFECT OF A HIGHER-YIELDING VARIETY ON SUPPLY RESPONSE



real total surplus is regressed. The other regressors include area sown and price of crop.

Results of analysis

The benefit/cost performance indicators derived are summarized in Table 1. Net present value (NPV) totaled approximately $1.4 billion for wheat, $227 million for barley, $243 million for rapeseed and about $64 million for forages in constant 1971 dollars. The average return or benefit/cost ratio for every dollar spent was 42:1 for rapeseed, 29:1 for wheat, 11:1 for barley and 3:1 for forages.[11] The internal rates of return were highest for rapeseed at 51%, followed by wheat at 29%, barley at 22% and forage (alfalfa) at 14%. Every additional dollar spent on research in each of these four crops would have generated a societal gain (an increase in the surplus) of about $78 for wheat, $14 for barley, and $23 for rapeseed, but only 50¢ on the dollar for forages.[12]

Canadian producers garnered roughly two-thirds of the total benefits obtained from research in wheat and rapeseed, while Canadian consumers obtained about the same proportion of these benefits from barley and three-quarters of the benefits from forage research. Foreign consumers derived much smaller benefits: less than 10% for wheat and less than 5% for the other three crops. The proportion of benefits of CPDR likely to be captured by private sector seed companies is considered to be negligible. For this reason, the effects of the recent passage of plant breeders rights legislation to promote private sector crop breeding research is unlikely to be so strong or so immediate as to allow for any significant reduction of Agriculture Canada investment in such research in the short to medium term.

In this analysis, the effects of trends in input costs and short-term fluctuations in weather patterns are isolated to the extent possible. However, in as much as extreme weather effects (such as serious drought conditions) recurring over the long term cannot be taken into account, the influence of weather patterns as a possible explanatory variable of yield differentials between new and old varieties is only partially isolated. For this reason, these benefit/cost performance indicators must be interpreted as indicative rather than as definitive statements of the program's past objective achievements.

The results of benefit/cost analysis are necessarily sensitive to the discount rate employed, the assumptions for the time streams of benefits and costs, and for the lag effects between research activity and results. The last two sets of assumptions are based on the advice of expert scientists. On the other hand, the discount rate assumption is based on extensive consultations with professional economists.[13]

TABLE 1 TOTAL RETURNS FROM HIGHER-YIELDING VARIETIES

Crop	Net present value of benefits (1971 $ million)	Benefit/ cost ratio	Internal rate of return (%)	Value of marginal productivity per additional dollar expended ($)
Wheat	1380	29:1	29	77.80
Rapeseed	243	42:1	51	23.40
Barley	227	11:1	22	13.70
Forage[1]	64	3:1	14	0.50

[1] Data limitations and time constraints led to the selection of alfalfa as a proxy for all other forage crops.

Source: Furtan and Ulrich, 1985.

In spite of the fact that forage crops are the second most valuable crop grown in Canada, there is a severe lack of basic data in almost all aspects of forage production. There is a lack of meaningful information on prices and on quantity and quality of various types of forage. Moreover, in contrast with the major grains and oilseeds, no consistent annual forage variety survey is carried out. Such a survey would provide a major feedback instrument to assist crop forage breeders. For these reasons, it is necessary to develop experimental data bases for the forage analysis; therefore, the measures of net societal benefits from forage breeding are, at best, indicative.

The distribution of professional person-years allocated to agricultural research and development is generally used as a second-best measure of the relative contribution of Agriculture Canada in this field, vis-à-vis that of other participants. In an authoritative examination of this issue, D.G. Hamilton (1980) states that Agriculture Canada contributed about 60% of all professional person-years in agricultural crop breeding in 1977. If this figure is accepted, at least 60% of the net present value

benefits from crop research (see Table 1) can be attributed to Agriculture Canada. This must be considered a very conservative estimate, as Agriculture Canada plays a linchpin role in crop research[14] and much of the research done by other agencies is contracted out by Agriculture Canada. In the opinion of many experts, the Agriculture Canada contribution was a necessary condition for the significant technological improvements in crop production occurring in the postwar period in Canada.[15]

Impacts on regional economic growth[16]

The tool of analysis for this module is Statistics Canada's 1979 regional input-output model of the Canadian economy. Input-output simulations were conducted to generate estimates of the effects of the production increase due to the use of higher-yielding crop varieties on final demand sales, employment, sectoral revenues, induced imports and government revenues.

The impact on farm gate receipts in the most recent year (1983) arising from the introduction of higher-yielding varieties of wheat, barley and canola-rapeseed crops over the period 1972-83 was estimated to be the difference between the value of 1983 production and what the 1983 production would have been, had only old (pre-1972) varieties been grown.[17] The instrumental variable modeled was the impact of higher-yielding varieties, not other characteristics such as increased disease resistance or resistance to lodging.

Method of analysis

Input-output analysis is a modeling approach that analyzes the relationship between changes in the output of particular industries or sectors (such as the primary production of wheat, barley and rapeseed) and any consequent changes in the output of other industries or sectors.

The rectangular Statistics Canada commodity-by-industry input-output matrices show the commodity outputs of each industry and the use of these commodities either as inputs by other industries or as sales to the final demand categories of personal consumption, capital formation (including investment in plant and machinery), government purchases and exports.

The model also calculates the direct and indirect effects on all industries of a given increase in the output of a particular commodity. The direct effects are the increases in inputs required by the industry producing the given commodity output. Indirect effects are the increases in outputs of the industries that supply inputs to the originally impacted industry, plus the increased outputs of industries that supply them in turn with inputs, and so on.

The model estimates impacts using technological coefficients derived from a base year (1979) for analyzing the impact in 1983; similarly, the relationships between relative factor costs of industries and their product prices are specified for the base year 1979.

It is necessary to make various simplifying assumptions in input-output modeling. These include constant returns to scale[18] (output is proportional to input) and constant technology (inputs are always combined in the same proportions).

In addition, an open-model assumption is used in which only first-round effects are considered and income is not respent. A closed-model assumption simulating the multiplier effects from the continuous rounds of respending of the initial income effects is not employed.

Despite these limitations, input-output analysis is a powerful tool for analyzing the regional economic impacts of past investment activities, such as those to improve the yield of major Prairie crops such as wheat, barley and rapeseed.

Results of analysis

The farm gate value of increased production of wheat, barley and canola attributable to new crop varieties in 1983 was estimated to be about $662 million.[19] Table 2 summarizes the input-output simulations of the impacts on employment, sector incomes, government revenues, and imports arising from the crop research-induced increase in the value of final demand sales of wheat, barley and rapeseed in 1983.

The input-output simulations generate the following findings. The employment effect of the additional production generated by crop research was 8557 person-years of paid employment in 1983, with 6325 person-years of employment occurring in the Prairie provinces and 2232 person-years elsewhere in Canada. The agriculture industry received the largest employment creation (2136 person-years), with the transport and storage industry being the next most affected sector (2002 person-years). Of the total gross domestic product (GDP) effect of

TABLE 2 ECONOMIC IMPACTS FROM SELECTED HIGHER-YIELDING GRAINS AND OILSEEDS, CANADA, 1983[1]

	Prairies	Rest of Canada	Total
Employment effects (person-years)			
Agriculture	2125	11	2136
Food and beverage	101	58	159
Transport and storage	1457	545	2002
Chemical products	83	165	248
Other industries	2559	1453	4012
TOTAL	6325	2232	8557
GDP effects (1983 $ million)			
Agriculture	429.6	1.4	431.0
Food and beverage	6.1	2.3	8.4
Transport and storage	53.7	23.2	76.9
Chemical products	8.1	7.2	15.3
Other industries	125.1	49.2	174.3
TOTAL	622.6	83.3	705.9
Induced imports (1983 $ million)			
	53.2	17.6	70.8
Government revenue (1983 $ million)			148.6

[1] The higher-yielding varieties of wheat, barley and canola-rapeseed examined were introduced during 1972-83 and the resulting increased production had a farm gate value of $662 million in 1983.

Source: Canadian Loric Consultants Ltd., 1985.

$706 million, the agricultural sector experienced the largest stimulus ($431 million), followed by the transport and storage sector ($77 million). The Prairie GDP effect was $623 million, or 88% of the national impact. The effect on government revenues was to increase these by $148 million in 1983. And the introduction of higher-yielding varieties of wheat, barley and rapeseed over the 1972-83 period induced $71 million of imports in 1983. Since no Keynesian-type multiplier effects are included, these input-output effects should be regarded as minimal (conservative) indirect economic impacts. The development of canola also encouraged the development of oilseed processing facilities, as both oil and meal quality was improved in the new Canada rapeseed varieties, but the multiplier effects as a result of expanded oilseed processing facilities cannot be determined.

Effect on marginal land utilization

This portion of the analysis examines whether the development of new, higher-yielding varieties of major Prairie crops over the 1971-81 period has been responsible for any changes in the cultivation of marginal land or in the crop mix on marginal lands.

Expert opinion was consulted to ascertain the likely impact on new marginal land utilization (Canada Land Inventory Classes 4 and 5 lands) of the introduction of new varieties of wheat, barley and rapeseed during 1971-81. While more than half of the expert group felt there was virtually no impact, the remainder felt the introduction of new crop varieties had an effect on marginal land use, but that it was very small compared with the influence of other factors. According to the latter group, the introduction of higher-yielding new varieties augmented the use of marginal lands (CLI classes 4 and 5) by only 3%. More important considerations in increasing marginal land use were such factors as market prices, shipment quotas, the farmer's financial position, and the ability and desire to expand the farm.

The experts were unanimous in viewing the introduction of new crop varieties as a significant stimulus to farm efficiency. This stemmed from the subsequent ability of farmers to respond more rapidly to changing market conditions, outbreaks of pests and diseases, and requirements to develop superior crop rotation cycles. While most of the experts could not quantify this impact on farm production efficiency, they believed that Canada would pay a heavy price if new varietal development was curtailed.[20]

Other impacts on the agricultural land base

The additional land base required in 1983 to maintain the same level of production of wheat, barley, and rapeseed in the absence of new varieties (that is, those introduced after 1971) was estimated. The additional land requirement, if the older (pre-1972) varieties had been produced in 1983, would have been about 2.1 million hectares for the same pattern of fertilizer use and crop management practice that prevailed for the actual crops in 1983. This corresponds to an equivalent bread wheat yield advantage of the new varieties of 3.5 million tonnes.

Impact on Canada's international trade position

This portion of the analysis addresses the extent to which any increased volume and value of exports over the immediate past period (1971-83) may have been attributed to Agriculture Canada's Crop Production Development Research Program (see McClatchy, Finn and Heimbecker, 1985).

Method of analysis

The question posed is whether an increase in any Canadian grain exports (generated by the commercial replacement of new higher-yielding varieties for old, lower-yielding ones) might have lowered world export prices for these crops. If the answer is yes, then it can be argued that crop research allocation decisions should perhaps take the possible price effects of production changes into account, because a significant part of the net benefits of Canadian crop research might very well accrue to foreign buyers.

The following critical assumptions underlie the estimation of the export revenue-enhancing effects in 1983 from the commercial introduction of new higher-yielding varieties after 1972. It is assumed: new crop varieties did not differ from old crop varieties with respect to their qualitative characteristics (the exception being canola-rapeseed); for any crop, the area sown would have been the same in a given year in the absence of new varieties; the relative yields of varieties of any given crop, as observed in the published crop breeders test results, were reflected in the relative yields of those same varieties for on-farm production; and if the price elasticities of export demand were high, then the increase in the value of exports would be roughly equivalent to any corresponding domestic production-expanding effects.

Results of analysis

There are two steps to this analysis: first, estimation of the export elasticities of demand for grains and oilseeds facing Canada in the 1970s; and second, estimation of CPDR's contribution to production (and to exports).

To estimate the export elasticities of demand (*EXD*)[21] for grains and oilseeds facing Canada in the 1970s, the elasticities of supply and demand and the average volume of consumption and production of the major grain and oilseed trading nations need to be established for the 1971-81 period.

A country can affect world (trading) prices by changing its own export volume. This world market power will be greater if the country's traded share of total world consumption and production is greater and if the price responsiveness of both demand and supply in foreign countries is less (more inelastic). The price responsiveness of foreign demand and supply depends, in turn and among other things, on the extent to which the commodity in question can be easily substituted for other commodities in consumption and in production respectively.

The Canadian EXD for each commodity is calculated according to the formula:

$$EXD = \frac{1}{\mathrm{CX}} \left[(\Sigma_j EX_j \cdot QD_j) - (\Sigma j\, ES_i \cdot QS_i)\right] \qquad (1)$$

where

- i, j = 1, 2 ....n; number of countries or country groupings in the trading world;
- ED_j = elasticity of demand in the *j*th country;
- QD_j = quantity of consumption in the *j*th country;
- ES_i = elasticity of supply in the *i*th country;
- QS_i = quantity of production in the *i*th country; and
- CX = quantity of Canadian exports.

"Best estimate" foreign supply and demand elasticities may be assumed after considering the results of a range of published research and of the elasticities adopted in several other analytical frameworks. However, some difficulties encountered in obtaining estimates for certain individual commodities require some commodity aggregation. Thus bread and durum wheat are combined, as are oats, barley and rye. The country aggregation adopted also varies by commodity, depending on the importance of individual countries in the world market and the perceived uniqueness of their supply and demand characteristics. The absolute elasticities of export demand (*EXD*) for wheat is 11.7, for barley, oats and rye 26.5, for flaxseed 11.5 and for rapeseed 19.1. These figures indicate the percentage increase in Canadian exports that would have depressed price received by 1% during 1972-81.

The result of this analysis is that the price effect due to increased Canadian export volumes during the 1970s was small in all cases. Past experience suggests that Canadian research managers therefore need not concern themselves with the possible international price effects on these crops from domestic yield improvements when making resource allocation decisions for crop breeding to generate higher-yielding varieties. Hence, any increase in domestic production attributable to the introduction of new, higher-yielding varieties would be largely reflected in increased export receipts.[22]

The value of the additional exports receipts in 1983 attributable to new CPDR varieties would have approached approximately $530 million, which is the production-augmenting effect from introducing the new varieties, assuming a relatively inelastic domestic demand for these commodities.[23]

CONCLUSION

The results of the impact/effect analysis of past CPDR program expenditures can be summarized as follows.

The net societal benefits of the wheat, barley and rapeseed programs obtained in the benefit cost analysis were very high: 42:1 for rapeseed; 29:1 for wheat, 11:1 for barley and 3:1 for alfalfa forage.

The Prairie-wide regional economic impacts of the program obtained in the input-output analysis were very significant, as were those for government revenues nationwide.

The production-augmenting effect from introducing new higher-yielding varieties was probably largely reflected in a corresponding expansion in export receipts in light of the very elastic foreign demand for these commodities. Agriculture Canada's Crop Production Development Research program, by improving the supply-side stability of the Prairie crop sector, serves to make Canada a more reliable exporter to the world grain and oilseed market and contributes to the prosperity of Prairie grain producers.

The effect of new varietal introduction on new marginal land utilization over the period 1972-81 was minimal, according to expert opinion. About 97% of the newly cultivated marginal land would have been cultivated even in the absence of new varieties.

The Crop Production Development Research program has proved to be a soundly conceived and cost-effective program in a period when research resources were relatively plentiful. A federal crop research effort remains a prerequisite for agricultural sector growth, competitiveness and stability.

NOTES

1 Paul Finn is Evaluation Research Manager, Program Evaluation Division, Agriculture Canada, in Ottawa.

2 See Treasury Board (1980), p.6.

3 Haploiding is the development of adult gamete cultivars (with one-half the usual number of chromosomes) to combine with other gametes to create new varieties.

4 An expert group of crop scientists contacted as part of the CPDR evaluation suggested that periodic major crop losses would almost certainly result, if maintenance research were not to be carried out.

5 It was postulated that Canadian research efforts did not likely affect most foreign producers' supply response for these crops, since the new varieties were developed for unique Canadian climatic conditions. It was impossible to determine whether countries with similar climates, such as the USSR and China, benefited from such past Canadian research.

6 Maintenance research is undertaken to preserve a crop variety's characteristics in the face of the dynamic production environment (to ensure continuing rust resistance, for example).

7 The data base comprised the Prairie Grain Variety Survey, conducted by the wheat pools of the Prairie provinces; the Co-operative Variety Trials (conducted each year jointly by Agriculture Canada and the Prairie universities); and Crop Variety Yield Indices, published by the provincial Departments of Agriculture for each of the Prairie provinces.

8 The emphasis of rapeseed breeding during the latter part of the period (1961-83) was significantly changed to incorporate improved quality characteristics (i.e. lower levels of erucic acid, glucosinolates and fibres). The term "canola" has been introduced to designate these high-quality varieties of rapeseed.

9 Consumer-producer surplus analysis is partial equilibrium analysis. The notion of consumer surplus is that some consumers would be willing to pay higher prices for certain quantities of product because of the downward-sloping nature of the demand curve. Consequently, it is assumed that the area under the demand curve is a measure of the total satisfaction (utility) derived by all consumers for the good, assuming that the income effect associated with changes in the price of the good is zero, and that the marginal utility of income is the same for all consumers. Hence the total utility of a good or service for a consumer is the price he pays plus the consumer surplus.

The area under a supply curve is assumed to measure the social opportunity cost of resources used to produce a good. Hence the total utility of a good or service a producer furnishes is the price he demands plus any producer surplus. Although the extent of the producer surplus associated with any given supply curve and its intersection with a demand curve does not equate to profits as conventionally measured, a

change in producer surplus associated with a shift in a supply curve tends to be associated with profitability.

[10] A rightward shift in supply is synonymous with an increase in aggregate production, given the same expenditure of financial resources.

[11] It is advisable to calculate several summary statistics when evaluating a given program to view it from more than one perspective. Given the availability of public funds, programs should be undertaken when they yield positive net present values, when benefit/cost ratios exceed unity, or when internal rates of return are greater than the social rate of discount. But if there is a constraint on the availability of public capital, then it is proper to judge the efficacy of programs primarily in terms of their benefit/cost ratios, selecting each marginal project until the availability of public capital is depleted.

[12] The low return to forage breeding, particularly the low value of marginal productivity, can be attributed to the low adoption rate for new forage crops and to the difficulty in making significant yield improvements in new forage crop varieties.

[13] Despite much discussion in the public finance literature, there is no concensus on the appropriate rate of discount to be used when evaluating public programs.

[14] P. Cooper (1984) finds that about two-thirds of new domestic grain and oilseed varieties and just under three-quarters of new forage varieties developed in Canada were Agriculture Canada varieties.

[15] This probably holds true even for barley, despite research funding by the malting and brewing industry.

[16] See Canadian Loric Consultants Ltd. (1985).

[17] Rapeseed had to be treated in a special way because old varieties were not planted after 1980. Thus a hypothesized rapeseed production level had to be estimated for 1983, based on the assumption that there was a close correspondence between the 1983 yields of the major old rapeseed varieties and certain new varieties of canola, based on their respective average yields for trial data over a number of years.

[18] Experts have indicated that the increased production attributable to new crop varieties was obtained without proportional increases in the major input categories of fertilizer and chemical inputs. To the extent that this is true, the increased production and employment created in the chemical products industry is overstated, and profits in agricultural crop production are understated.

[19] The farm gate value of the increased outputs of new varieties of wheat, barley and canola was estimated to be $495 million, $68 million and $99 million, respectively. Included as new varieties were Neepawa wheat and Bonanza barley, which were introduced in 1971 but largely popularized during the subsequent period.

[20] A few experts believed that, if the program was terminated, the absence of the mitigating effect of new crop varieties on losses induced by pests, disease and drought, would result in losses of 20% to 50% of crops in at least one of the next 10 years.

[21] The *EXD* is a measure of the degree to which export prices received depend on export volume; the higher this value, the more the nation is a "price taker" and its production does not influence world price. If $EXD = 1.0$, then changing the volume of exports will result in no difference in export receipts (lower prices will just offset higher volumes). If $EXD = 10.0$, a 10% increase in exports will result in a 1% decrease in price, and therefore almost a 9% increase in export receipts.

[22] The contribution of new varieties to the actual production increases experienced between 1972 and 1983 were in the order of 24% for bread wheat, 39% for durum wheat, 58% for canola and 2% for barley (see figure).

[23] This estimate is lower than the $662 million of farm gate value obtained by Canadian Loric Consultants Ltd. because these are the effects of only those varieties attributable to CPDR program activities and exclude the contribution of the provincial governments and private industry. However, it includes, as does the Loric study, the new varieties Neepawa wheat and Bonanza barley, both of which were commercially introduced in 1971 but largely adopted in the subsequent period.

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Economic returns to pest control technologies in Canada

M. Stemeroff and D. Culver[1]

Food production in Canada is vulnerable to infestations from a variety of pests, especially weeds, insects, diseases and nematodes. If left uncontrolled, these pests, either in combination or in isolation, may reduce marketable yields and quality. However, the magnitude of crop losses from pests is extremely variable among crops, locations, and years. There are a number of techniques available for controlling agricultural pests; however, the application of pesticides is the most common. The level of pest control action applied to any one crop is generally dependent upon the degree of economic loss that may occur in the absence of controls (generally referred to by crop protection scientists as the "economic threshold" concept). The ratio of benefits to costs from pest control actions fluctuates widely from year to year and from crop to crop.

The purpose of this article is threefold: to outline and describe the technologies available for pest control, to review the economic benefits derived from pest control, and to assess the potential for increased benefits from pest control actions.

PEST CONTROL TECHNOLOGIES

Agricultural pesticides

Pesticides are chemicals that are toxic to plants (herbicides), insects (insecticides), fungi (fungicides), or nematodes (nematocides). These pesticides often display secondary biological activity on other groups of organisms (some herbicides also act as insecticides, for example), but are classified according to their primary use. The majority of pesticides are synthetic organic chemicals.

The pesticides used in Canadian agriculture are diverse in terms of their physical, chemical and biochemical properties. This diversity is beneficial because it enables pesticides to exert a variety of toxic actions. It can therefore be applied in numerous situations. The selectivity of pesticides is primarily dependent on the method and timing of application, the formulation used, the rate of application, action of the pesticide, and degradation and toxic action within and nontarget organisms exposed to the active ingredient.

The efficacy of pesticides and other pest control technologies has three distinct levels, which attempt to answer the following questions:

Primary efficacy: Is there a net reduction in pest populations relative to the absence of pest control?

Secondary efficacy: Is there a net reduction in plant or animal damage resulting from the pest control measure?

Tertiary efficacy: Is there an increase in or protection of the quantity and quality of marketable yield that results from the use of the pest control measure?

The most important measure is tertiary efficacy, because it is the only efficacy measure from which to determine changes in the marketable value of the commodity in question, which is the economic benefit of pest control.

Pesticide use by individual farmers varies according to regional pest complexes and the management style of farmers. Stemeroff and Madder (1985) compile cost of production surveys for a sample of crops in Canada and the United States. Results indicate that average farm pesticide expenditures account for anywhere from 1.5% to 18% of total costs of production, and between 2% and 23% of total variable costs of production, depending on the crop and location. Generally, pesticides in fruit and vegetable production account for higher shares of production costs than those used for cereal crops.

Biological control

Biological control refers to the use of predators, parasites or pathogens to reduce pest populations. This may entail the introduction of natural enemies of pests into new regions, inundative release of parasites and pathogens, or habitat modification to promote natural enemies. A classical example of biological control is the "sterile insect" release program conducted in British Columbia for the control of the codling moth on apples (Proverbs et al, 1982).

Genetic control

Methods of genetic control include the use of resistant varieties as well as of genetic manipulation of the pest itself. The use of resistant varieties has been an important tactic for reducing pest damage, as exemplified in the development of sawfly-resistant red spring wheat varieties in western Canada.

Cultural control

Cultural control refers to any crop management practice affecting pest populations. These methods are usually low in cost and provide long-lasting but less dramatic effects on pest populations than other control measures. Cultural methods include tillage practices, crop rotation, time of planting and harvesting, sanitation, destruction of alternate hosts, planting of trap crops (the use of noncommercial plants to attract pests away from commercial plants), and the use of pest-free seed. For example, it has been demonstrated that the removal of onion culls (rejects) from the field after harvest greatly reduces the overwintering population of onion maggots and thus hinders initial populations the following season.

Integrated pest management (IPM)

IPM is more a philosophy of pest control than a technology. Specifically, it is a philosophy which promulgates the tolerance of some pest damage below that of economic significance while initiating "optimum" timing and selection of pest control technologies when necessary. Central to this philosophy are two key elements: first, the use of pest control actions only when necessary, usually based upon some pest-monitoring technique which indicates when pest populations exceed some minimum economic injury level and, second, a mix of pest control technologies rather than total reliance upon one technology.

IPM has become a popular rallying point for crop protection scientists since the numerous disclosures of adverse health and environmental effects from pesticide use in the 1960s. It remains a common aspiration that IPM will herald in a new era of pest control that is more sensitive and responsive to the health and environmental concerns.

Currently, an IPM program based on true economic injury levels and economic thresholds with cost-effective and practical monitoring technology does not, as yet, exist (Poston et al, 1983). The IPM programs which have been implemented are to a large extent pest-monitoring programs and are not true IPM. True IPM programs attempt to integrate all known crop protection technologies (biological, cultural and chemical controls) into one unified effort to control pests. These programs monitor pest populations and use, at best, simple economic thresholds to identify potential pest problems. In addition, pesticides are most often the only technology recommended, since no other technologies are sufficiently refined to do the same job at competitive costs as pesticides.

DEVELOPMENT AND USE OF AGRICULTURAL PESTICIDES IN CANADA

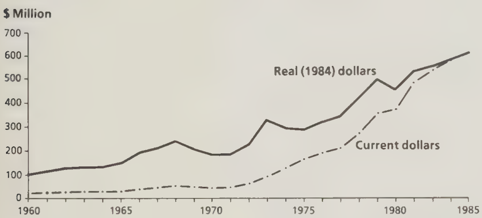
Since the advent of DDT in 1939, pesticides have been and remain the primary technology used for controlling pests. The widespread use of other technologies has not materialized. Pesticides sold in Canada are almost always first developed and marketed in other countries (such as the United States or western Europe). If successful in these other markets, the active ingredient(s) are imported into Canada via Canadian subsidiaries to be reformulated into new products for specific domestic uses. In the past, this arrangement served Canadian agriculture well, but now it is evident the rate of new pesticide introductions is rapidly declining in Canada. This situation is attributable to a number of factors, including the rapidly escalating costs incurred for screening and developing new products for the Canadian market, and the high costs incurred for meeting strict regulatory guidelines.

The Canadian pesticide industry is comprised of 40 companies employing approximately 4000 people. Three companies alone account for nearly 50% of total pesticide sales, thus indicating a high degree of industry concentration. The pesticide industry estimates that the cost of developing a new pesticide (introducing a new active ingredient) for the Canadian market has risen from $5.5 million in 1970 to approximately $25 to $30 million in 1985.[2] These costs represent expenditures for the development of product chemistry, toxicology studies, metabolism studies, residue studies, environmental chemistry studies, environmental toxicology studies, and efficacy and crop tolerance studies, to name just a few. Much of the

domestic pesticide industry's effort is also channeled into the development of new formulations of existing active ingredients, which costs considerably less than that for new active ingredients, estimated at anywhere from $2 to $10 million depending upon the extent of the change in new formulations. Specifically, if the amount of the active ingredient changes more than 10% from the original registration, then all-new toxicology studies are required.

Annual sales of agricultural pesticides in Canada have rapidly increased from less than $50 million in 1960 to more than $600 million in 1984 (Figure 1). For comparison, the annual sales figures have been inflated to 1984 dollars against the Statistics Canada petroleum price index for 1960-70 and the farm input price index (pesticides) for 1970-84. In constant (real) dollars, the value of pesticide sales has increased by a factor of five since 1960.

FIGURE 1 ANNUAL AGRICULTURAL PESTICIDE EXPENDITURES IN CANADA, 1960-84[1]



[1] Farm Input Price Index (pesticides) used to determine real expenditure

Source: Statistics Canada, cat. nos.21-202, 62-004.

When pesticide sales are broken down into their constituent parts (herbicides, insecticides and fungicides), it is evident that there have been significant changes in the relative sales of each their constituent parts (herbicides, insecticides and fungicides), it is evident that there have been significant changes in the relative sales of each group in Canada and the United States (Table 1). Specifically, sales of insecticides and fungicides have declined over time, while sales of herbicides have increased over the same period.

TABLE 1 PROPORTION OF PESTICIDE SALES BY MAJOR PESTICIDE GROUP IN SELECTED YEARS, CANADA AND THE UNITED STATES (% OF TOTAL PESTICIDE SALES)

Year	Herbicides	Insecticides	Fungicides	Other
Canada (agricultural sales only)				
1960	49	37	14	–
1965	51	38	11	–
1970	60	33	7	–
1975	80	16	4	–
1983	88	8	4	–
United States (all sales)				
1966	32	42	9	17
1971	47	34	9	10
1981	67	20	6	7

– = less than 1%

Sources: Statistics Canada, cat. no. 46-212; Crull (1985); and J.H. Elliott, President, Canadian Chemicals Association, Willowdale, Ontario, personal communication.

In addition to industry investment in pesticide development, both the federal and provincial governments commit substantial labor and material resources to research and extension of crop protection technologies. According to the *Inventory of Canadian Agricultural Research (ICAR*, 1984), approximately 408 person-years are devoted to crop protection research in Canada falling under the categories of entomology, weeds, or plant diseases. The majority of crop protection research effort is funded and directed by the federal government. Provincial governments, while conducting some research, are primarily responsible for disseminating crop protection technologies to farmers via provincial extension services.

FACTORS INFLUENCING THE ADOPTION OF PEST CONTROL TECHNOLOGIES

Pesticides

There are numerous factors influencing the rate of adoption of pesticide technologies by farmers. These include the severity of the pest infestation problem; the availability of registered pesticides or other pest control technologies; provincial licensing requirements for use of pesticides (apart from federal registration requirements, each provincial government has the power to regulate how any pesticide may be used within its borders); efficacy of the pest control technology; the cost of one pest control technology relative to other technologies and crop value; recommendations made by provincial extension personnel; industry sales promotions and advertising; compatibility of the pest control technology with other farm management practices; and perceived risks associated with the use of each pest control technology.

Pesticide technologies may be characterized as relatively simple, requiring few changes to the production system, and potentially very profitable to the farmer. With these characteristics, the introduction of new pesticides is often followed by high adoption rates. As an example, the use of Treflan QR5, a selective granular preemergent herbicide, increased from 242 000 ha treated in 1978 to 929 000 ha in 1983 (White, 1984).

IPM

The introduction and adoption of IPM by farmers appears to vary widely by region and by crop in Canada and the United States. In Canada, IPM on apples was first introduced in Nova Scotia in the 1940s, followed by Ontario in the early 1970s and then by British Columbia in the mid-1970s. Although some apple growers in Quebec may be influenced by the IPM philosophy, there is currently no IPM monitoring system operating in the province for apples. Today IPM influences approximately 90% of all apple growers in British Columbia, Ontario and Nova Scotia. Currently, IPM is limited to other small-area crops such as onions and carrots, although plans exist for the extension of IPM to larger-area crops such as corn in Ontario.

Until recently, IPM has been largely targeted to efforts to control insects and disease, with little emphasis on weed control. The major impact of IPM has therefore been on the use of insecticides and fungicides. With this in mind, Table 1 indicates that herbicides in Canada constitute approximately 88% of all pesticide sales; consequently, IPM is mainly applicable to only 12% of the pesticide market. In contrast, herbicides constitute 67% of pesticide sales in the United States. IPM therefore has more scope for impact in that country.

Greene et al (1985) indicate that IPM practices in the U.S. are prevalent for soybeans in most regions while they are practiced only sporadically for fruits and vegetables. They argue that this variability is due to the newness of the program, to uneven technological and public support, to relative value of target crops, and to environmental variability.

One of the most important factors serving to inhibit the adoption of IPM in Canada is the perception of increased risk associated with it (Stemeroff, 1981). Risk is frequently cited as a deterrent for technological change, especially in the case of pest control technology. Stemeroff (1981) demonstrates that, since the effects of pest monitoring are not known with certainty at the time of use, growers' initial reactions are to apply pesticides on a regular schedule primarily to act as insurance against potential crop loss. Lambur et al (1985) argue that early adopters of IPM tend to be better educated, to own larger commercial operations, to be more profitable, and to possess a more positive orientation toward new ideas and practices. Usually these same early adopters are opinion leaders for other growers; consequently, they are often sought out to legitimize a questionable new practice before it is widely adopted and implemented. The important point is that, if growers can prove for themselves the validity of IPM and if IPM complements the rest of their farm management practices, there is high probability that the innovation will be adopted by the majority of growers over time.

MEASUREMENT OF ECONOMIC BENEFITS

Pesticides

The primary economic benefits expected from crop protection measures may include increased marketable yield, improved quality, and/or reduced risk of crop loss from pest infestations. Usually, economic studies of crop protection focus

upon the first benefit, namely, changes in marketable yield, and compare this benefit with the cost of crop protection to derive a general benefit/cost measure (Stemeroff and Madder, 1985). The results of an extensive literature review indicate that, for each dollar spent on pesticides by farmers, the return was anywhere from a loss of $1.02 to a gain of $13.85 (Table 2). Stemeroff and George (1983) incorporate into their analysis the value of publicly funded research and of extension expenditures, as quantified by *ICAR* and provincial governments, respectively.

Krystynak (1983) examines the economic impact of 2,4-D in Canada. Using 1979 yield data, he estimates the annual net benefit in grain value with 2,4-D at approximately $176 million, on average.

Dunnett (1983) looks at captan use and finds that the control of fungal diseases with captan in Canada prevents crop losses valued at an estimated $100 to $150 million per year, assuming that no fungicide replacement is employed. He further points out that the degree to which these estimated losses can be avoided depends upon the availability and use of alternative fungicides.

TABLE 2 SUMMARY OF THE ECONOMIC RETURNS TO PESTICIDE USE ON SELECTED CROPS, UNITED STATES AND CANADA

Author(s)	Crop(s)	Pesticide(s)	Location	Benefit/cost ratio
Headley (1968)	all	all	U.S.	4:1
Langham et al (1972)	all	all	U.S.	-1.02:1 to 13.85:1
Miranowski (1975)	corn	insecticides	U.S.	2.02:1
		herbicides	U.S.	1.23:1
	cotton	insecticides	U.S.	1.82:1
		herbicides	U.S.	1.48:1
Campbell (1976)	tree fruit	all	British Columbia	12:1
Fischer (1970)	apples	all	Nova Scotia	13:1
			Quebec	5:1
			Ontario	2.34:1
Schroder et al. (1982)	corn	herbicides	U.S.	3.30:1
	soybeans	herbicides	U.S.	2.30:1
Stemeroff and George (1983)	onions	insecticides	Quebec	3.40:1
			Ontario	11.2:1
			British Columbia	8.9:1
	apples	insecticides	Nova Scotia	4.1:1
			Quebec	2.6:1
			Ontario	3.9:1
			British Columbia	3.6:1
	potatoes	insecticides	Maritimes	7.3:1
			Quebec	3.7:1
			Ontario	7.3:1
			Prairies	7.9:1
			British Columbia	3.7:1

Source: Adapted from Stemeroff and Madder (1985).

The quantification of benefits from pesticide use in agriculture (Table 2) has done much to inform researchers and policy decision makers of the degree and variance of benefits from pest control measures. However, numerous weaknesses permeate most economic assessments of pest control. Some of the most important are as follows.

Results are generally presented in absolute terms or in some cases with narrow benefit ranges, which are determined in an *ad hoc* manner, as detailed by Roberts et al (1985) and the NAS (1980). It is impossible to realistically quantify economic benefits of pest control without extremely large error limits, because of the large degree of uncertainty surrounding tertiary efficacy and economic data.

No economic studies to date quantify the long-term benefit/cost ratio of implementing pest control technologies. This poses a serious problem for decision making, which involves long-term commitments of scarce resources, as demonstrated by Carlson (1977).

Attention is rarely given to the distribution of benefits among groups in society resulting from the use of pest control technologies. For example, most studies assume perfect price-elasticity of demand facing growers who employ crop protection technologies; therefore, all the benefit accrues to growers. In most cases, this assumption proves realistic for Canadian agriculture; however, it is important to consider other secondary economic impacts, such as changes in employment in farm input supply industries as well as changes in macroeconomic indicators, including trade, national income, and so on.

IPM

IPM is a relatively new terminology for an old approach to pest control. At present, IPM is practiced on small-area crops at a basic level only, namely, pest monitoring. Currently, the aim of pest monitoring is to use information (regarding economic thresholds) to replace "regularly timed spray" schedules with "spray as you need" schedules, such that the use of pesticides is optimized (in most instances reduced), and/or the risk of crop loss is diminished. The ultimate goal of pest monitoring is to employ as few pesticides as possible to obtain optimum economic benefits, whether improved yields or quality of product.

Research indicates that there is potential for a wide range of benefit/cost measures with IPM (Table 3). In the United States, benefit/cost ratios of 1:1 to 48:1 have been determined for IPM. In Canada, a benefit/cost ratio of 4:1 for apples has been calculated for Ontario (including public expenditures for research and extension). However, recent research by Evans and Stemeroff (1986) indicates that for IPM on carrots in Ontario the cost of IPM research, extension and maintenance falls short of the value of pesticides saved, while the benefit/cost ratio for onions is 3:1. The carrot IPM results, although negative, do not imply that IPM does not pay for itself. Rather, serious omissions in quantifying benefits have been made. Specifically, the reduction of risk of crop loss to growers and increases in marketable yields for growers implementing IPM are known to be achieved but are unquantified. Indeed, by allowing for an increase of only 1% in carrot yield, the benefit/cost ratio for carrot IPM increases to 1.5:1.

TABLE 3 SUMMARY OF BENEFIT/COST RATIOS TO IPM ON SELECTED CROPS, UNITED STATES AND CANADA

Author(s)	Crop(s)	Location	Benefit/cost ratio
Araji (1981)	corn	U.S.	24:1
	potatoes	U.S.	5:1
	tomatoes	U.S.	33:1
	apples	U.S.	1:1
	onions	U.S.	4:1
	lettuce	U.S.	48:1
	carrots	U.S.	2:1
Stemeroff and Madder (1985)	apples	Ontario	4:1
Evans and Stemeroff (1986)	onions	Ontario	3:1
	carrots	Ontario	0.5:1

Source: Compiled by authors.

POTENTIAL FOR INCREASED BENEFITS FROM PEST CONTROL

The continued use of pesticides in isolation from other technologies and applied in high volumes does not provide much opportunity for increased productivity. This is mainly due to the rapid development of pesticide resistance (particularly in insecticides and fungicides) and the rising costs of pesticide development. Currently, pesticides provide the most readily available and cost-effective form of crop protection relative to other technologies.

There are two major means of making crop protection more cost-efficient, namely, adopting the IPM philosophy more widely and taking advantage of biotechnology.

IPM

IPM, if extended to other large-area crops, has the potential for increasing agricultural productivity, as in the examples of apples and onions described above. However, the feasibility of extending IPM to large-area crops such as canola and wheat is uncertain without a more detailed economic and biological evaluation.

The application of IPM to weed control has considerable potential; however, more biological evaluation and research is required to develop practical IPM systems for this pest.

Biotechnology

Biotechnology in its most general definition is the utilization of a biological process, be it via microbial plant or animal cells or their constituents, to provide goods or services. Environment Canada (1985) lists five major techniques which form the basis of current biotechnology: genetic engineering, enzymes and enzyme systems, fused cell techniques, plant cell culture, and process and systems engineering.

It is argued by some (Crull, 1985) that biotechnology promises to offer the greatest potential for improving the productivity of pest control. The outlook is that there will always be a need for pest control, in particular pesticides.

According to Crull (1985), one of the central problems with pesticide use is its persistence in the environment, (especially the soil). One example where biotechnology has the potential to improve pesticide productivity is the genetic engineering of degradative microorganisms which alleviate the persistence problem (such as alachlor and aldicarb) by destroying undesirable, persistent compounds. Once persistence is controlled, many older and still effective pesticides could possibly be reintroduced for commercial use at a relatively low cost.

In other instances, potential exists for pesticides to be manufactured biotechnologically in the same manner as antibiotics, with probably lower environmental impact and increased control. Crull (1985) states that Monsanto estimates that about 30% of its sales will come from bioengineered products by the late 1990s. In addition to the above, bioengineering of plants themselves offers further potential for the next generation of pest control. For example, with current DNA transfer technology, a foreign gene could be inserted into a plant, which would render the new plant disease or insect resistant.

CONCLUSIONS

Since the Second World War, increased productivity in Canadian agriculture can be attributed to a number of crop management practices, such as tillage, fertility, plant breeding, irrigation, agricultural structure, and crop protection. It is recognized that productivity increases cannot be attributed to any one of these management practices in isolation. However, crop protection is unique because yield increases due to the first five management practices are usually followed by increased susceptibility of crops to pest infestation. This means the success of intensification largely depends upon whether the raised level of output can be maintained with crop protection.

Improved pest control technology and pesticides in particular have provided significant benefits to Canadian farmers in terms of increased profits and productivity. Consumers have also benefited from a high-quality supply of food at reasonable prices. The significant increases in productivity as a result of many crop management practices may not be sustained in the future as a result of resistance (particularly insecticides and fungicides) and other factors. The development of new pesticide technologies based on IPM and biotechnology offers potential for further productivity increases in Canadian agriculture and for environmentally safer pest controls. However, there remains the need for considerably more research in both these areas.

NOTES

[1] Marvin Stemeroff is a consultant with Deloitte, Haskins and Sells Associates of Guelph, Ontario, and David Culver is the head of technology assessment with Inputs and Technology Division, Agriculture Canada, in Ottawa.

[2] The authors would like to acknowledge the cooperation of J.H. Elliott, President of the Canadian Chemicals Association, Willowdale, Ontario, and G.B. Kinoshita, Manager, Research and Development, Pesticides Products, of Cyanamid Canada Inc., Willowdale, Ontario, in arriving at this estimate.

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Research, technology and productivity change in Canadian agriculture

F.L. Tung and G. Strain[1]

The Canadian agriculture and food industries have been able to meet rapidly changing consumer needs in both domestic and world markets thanks to the increasing integration of commercial enterprises, the flexibility of production practices and the availability of up-to-date technologies. In 1984, the gross value of Canadian farm production amounted to \$16.8 billion, down from the previous high of \$17.8 billion reached in 1981. In 1985, farmers utilized a capital stock (land, buildings, machinery and livestock) valued at \$115.3 billion, a labor force of 488 000 persons and other purchased inputs amounting to \$13.6 billion. Consumers spent \$36.8 billion on agricultural products, while revenues of \$8.9 billion were derived from exports. Only \$6.0 billion was paid for food imports.

The Canadian agriculture industry has played and will continue to play a vital role in the development of the Canadian economy. The rapid development was made possible by the efficient utilization of the country's abundant natural resources for food and fibre production. Research aimed at improving technology and hence productivity in the crop and livestock sectors has allowed the majority of Canadians to engage in other economic activities. These activities have produced the goods and services that make possible the high standard of living Canadians enjoy today.

A recent study suggests that agricultural productivity increased at an annual growth rate of 1.39% over the 1962-82 period.[2] Although there are many sources of productivity growth, it is certain that the efforts of the agricultural research community, both in Canada and abroad, have contributed significantly to such growth. Indeed, without agricultural research, new and improved production technology and farm management practices contributing to increased agricultural productivity might not have evolved. It would therefore seem that agricultural research is a vital component of productivity growth.

Although this proposition is generally accepted, empirical support is required. Therefore, the purpose of this article is to provide some empirical evidence to justify this proposition by examining the contribution of Canadian agricultural research and technology to productivity growth in the Canadian agricultural sector.

MEASUREMENT DIFFICULTIES

Empirical measurement of the contribution of research to technological development and hence to productivity growth is extremely difficult. The difficulty lies in isolating the portion of productivity growth attributable to technologies developed by domestic researchers from those developed abroad.

Another difficulty is isolating the portion of productivity growth attributable to technology resulting from research activities from the portions attributable to other factors, such as increased input use and structural changes. To facilitate an understanding of the empirical measurement of the contribution of research and technology to productivity growth, the balance of this section focuses on the relationship between these factors.

Domestic and imported research and technology

It is well recognized that not all technologies adopted by the Canadian agricultural sector are the result of research carried out by governments, universities, agri-business firms or innovative farmers in Canada. A large portion of the technology adopted by Canadian farmers is imported, especially from the United States. For example, many agricultural chemicals widely adopted by Canadian farmers over the past 3 decades have been developed by foreign researchers and are therefore considered to be imported technology. Widespread international technological exchange results in empirical difficulties in separating the portion of technology developed externally from that developed domestically. It is assumed that the relationship between domestic agricultural

research and imported technology is constant over time. This assumption results in a tendency to overestimate the contribution of domestic agricultural research to productivity increase when imported technology is included. However, the extent to which this bias exists is unclear, since domestic research and development are often enhanced by imported technology and research activities abroad. Thus, the contribution of imported technologies to productivity growth is inextricably linked to domestic research activities and technological development. For the remainder of the article, agricultural research is defined as those research activities carried out in Canada by governments, universities, agri-business firms and innovative farmers.

Research, technology and productivity

Productivity is a measure of the efficiency with which resources are transformed into goods and services. More simply, productivity can be defined as the ratio of aggregate output to aggregate input. Thus, productivity growth can result from changes to either aggregate output or input.

There are many potential sources of productivity change, including climate, public policy, market/institutional forces or technology through agricultural research, extension and education. The structure of farming, economies of size, the availability of capital, and restrictions on output/input use all can potentially affect productivity growth. In the long run, however, technology appears to be the most important force contributing to productivity growth. New technologies or techniques can affect productivity growth through new production processes that generate new outputs or inputs, new uses for old inputs, more efficient uses of old technology that results in more efficient enterprise combinations, more efficient use of resources within existing technology, or greater adoption of existing technologies. New technologies and techniques are the result of agricultural research, in the classical sense, as well as university and other extension programs, education, and the inventiveness of farmers and agri-business firms. Research contributes to productivity growth, either by making possible increased output with a given input, such as new varieties of crops and breeds of livestock, or by reducing the amounts of inputs needed for a given output as a result of improved production techniques for crops and livestock, improved machinery and equipment, control and/or eradication of the pests and diseases of livestock and crops. The contribution of research to productivity is achieved through a long-term, complex process. How this process affects productivity growth is discussed below.

Agricultural research, technology and production increase

One means by which research contributes to productivity growth is by increasing output with a given set of inputs. For example, ongoing research has resulted in the improvement of wheat varieties. This, in combination with the increased use of fertilizer and chemicals, has resulted in increases in wheat yields from 1.37 t/ha for the period 1961-65 to 2.06 t/ha for the period 1981-82. Agricultural research has also contributed to increased production in the livestock sector. The most noteworthy example of this is milk production. Research in combination with increased input utilization has resulted in an increase in milk production from 2939 L per cow during 1961-65 to about 4141 L per cow during 1981-82. These are only two examples of the impact of a wide range of research activities on production increases (Table 1).

However, a difficulty to be resolved when attempting to measure the contribution of agricultural research to productivity growth is how to measure the research and technology benefits that are realized gradually over an extended period of time. Typically, these benefits begin slowly as the technology is being developed and adopted by innovators, reaching a peak in the middle period as adoption spreads, and then decline in the latter years as this technology is replaced by an improved technology.[3] Clearly, the period over which research and technology benefits can be realized depends upon the nature of the innovation, as well as on the existing production practices within a region or among a target population of farmers. It is also necessary to isolate the portion of increased production attributable to the new technology.

TABLE 1 AVERAGE PHYSICAL PRODUCTIVITY OF MAJOR COMMODITIES, CANADA

Commodity	1961-65	1966-70	1971-75	1976-80	1981-82
Crops (t/ha)[1]					
Wheat	1.37	1.66	1.70	1.88	2.06
Barley	1.66	2.03	2.13	2.41	2.61
Rapeseed	0.91	0.95	0.97	1.19	1.29
Flaxseed	0.67	0.76	0.77	0.94	1.09
Potatoes	17.80	18.90	20.80	23.00	24.50
Grain corn	4.71	5.15	5.06	5.50	5.87
Soybeans	1.93	1.96	2.07	2.18	2.23
Poultry and dairy					
Eggs[2] (number per layer)	199	204	216	233	242
Milk[3] (L per cow)	2 939	3 338	3 962	3 808	4 141

Sources: [1] CANSIM, Statistics Canada.
[2] Production of Poultry and Eggs, Statistics Canada cat. no. 23-002.
[3] Dairy Statistics, Statistics Canada cat. no. 23-201.

Agricultural research, technology and input mix

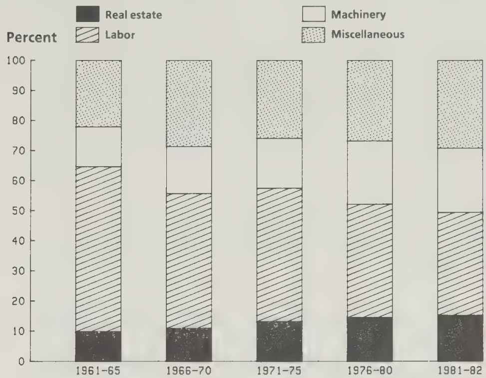
Another manner in which research contributes to productivity growth is through changes in input mix, allowing for more efficient use of all inputs. Over the last 3 decades, the input mix has changed significantly as a result of research, as well as changes in the relative prices of various inputs.

As shown in Figure 1, some inputs have fluctuated slightly in their share of the total input mix over the past 2 decades, while other inputs have increased or decreased significantly. It should be noted that the annual growth rate for total farm inputs from 1961 to 1982 was 0.66%.

Total real estate inputs, including the annual service costs of farm real estate, building depreciation, fencing expenses and property taxes, increased at an annual rate of 2.65% during 1961-82. Farm real estate's share of the input mix increased from 9.8 % during the 1961-65 period to 15.2 % during the 1981-82 period. The 1982 farm real estate input level increased by 65.2% since 1961.

Labor inputs, on the other hand, decreased substantially during the period of study. This input, including operator labor, hired labor and all unpaid family labor, declined at an average annual rate of 2.83%. Labor's share of the total input mix dropped from 54.8% during 1961-65 to 34.2% during 1981-82. Total farm output increased during the same period at an average annual growth rate of 2.36%.

FIGURE 1 FARM INPUT MIX IN RELATIVE SHARES



Source: Agriculture Canada.

A sizable portion of the labor force was replaced by labor-saving machinery. Machinery inputs increased their share in the total input mix from 13.3% in the period 1961-65 to 21.4% during the period 1981-82. Machinery inputs, including annual service costs of machinery inventory, machinery depreciation and machinery repairs, increased at an average annual growth rate of 3.85% between 1961 and 1982.

Crop inputs, including annual service costs of crop inventory, seed purchases, fertilizer expenses, pesticide expenses, twine, wire and container expenses, irrigation expenses and lime expenses, increased by 160.3% by 1982 over the 1961 level. This reflects an annual growth rate of 4.11% between 1961 and 1982. The major reason for the high growth of crop inputs is the increased use of fertilizers and pesticides. The crop input share of the total input mix increased from 11.6% during 1961-65 to 16.2% during 1981-82.

Energy inputs, including gasoline, diesel fuel, oil and lube expenses, heating fuel expenses for farm use, and electricity expenses, as a share of total inputs, was 5.0% during 1961-65 and increased marginally to 5.9% during the 1981-82

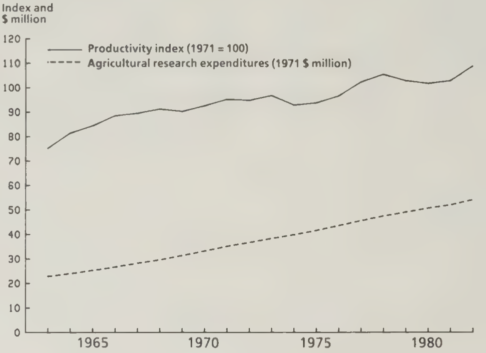
period, although the energy input level was 83.3% higher in 1982 than in 1961.

Miscellaneous input items made up 2.3% of the total input mix in the 1961-65 period and maintained a relatively constant share over the past 2 decades, increasing at an average annual growth rate of 1.39% for the 1961-82 period. Included in miscellaneous inputs are such items as net insurance expenses, custom work and "other miscellaneous" expenses.

CONTRIBUTION OF RESEARCH TO PRODUCTION AND PRODUCTIVITY GROWTH

The foregoing discussion indicates the difficulty associated with empirically measuring the contribution of research to productivity growth. The difficulty lies in attributing observed growth to research or to other factors such as increased input use and weather[4] and in what proportions. The allocation of productivity growth to the different production factors is best estimated using the production function approach. In economic theory, a production function is used to estimate the relationship between the various factors of production and output. This approach is employed by Brinkman in his efforts to analyze sources of multifactor productivity growth in Canadian agriculture.[5] In his study, Brinkman uses operating expenditures on agricultural research, federal, provincial and private education and extension programs as a means of measuring the impact of research and technology on agricultural productivity. It must be noted that expenditures on education and extension programs are included because they complement research by facilitating the adoption and application of new techniques. Operating expenditures on agricultural research and its supporting services (education and extension) are used as a proxy for the contribution of research and technology because of the difficulties associated with its measurement. Evidence suggests that expenditures on agricultural research and its supporting services are linked to increased agricultural productivity in a lagged relationship (Figure 2).[6] However, Brinkman does not include expenditures on capital items. Thus, in empirical estimation, the contribution of Canadian research and technology to productivity growth might be underestimated. Other independent variables include total inputs, weather (as measured by a weather index), and farm structure (as measured by the number of farms by gross sale class).

FIGURE 2 RELATIONSHIP BETWEEN PRODUCTIVITY[1] AND OPERATING EXPENDITURES[2] ON AGRICULTURAL RESEARCH



[1] 3-year moving average
[2] 14-year moving average
Source: Agriculture Canada.

Given the specification of the proxy variable for research and technology, Brinkman estimates several equations which, he suggests, allow for the estimation of the impact of research on productivity growth. Based on these equations, he estimates that a 1% increase in the overall funding for agricultural research and its supporting services would increase the productivity index, over a 14-year period, by between 0.25% and 0.33%. With respect to output specifically, over a 14-year period, each additional real dollar spent on agricultural research and its supporting services is estimated to generate between $10.50 and $17.00 of equivalent increased output for Canada as a whole (based on the 1980 nominal operating expenditure on agricultural research and its supporting services). Brinkman does not provide estimates for other factors contributing to productivity growth. He does, however, conclude that agricultural research and its supporting services is one of the highest payoff uses of public funds available in Canada today.

This report employs one of Brinkman's empirical equations to estimate the contribution of agricultural research and technology to production and productivity growth.[7] The

contribution of each factor to growth in output is estimated over time based upon the estimated coefficients (as noted below). The results are then converted into estimates of the contribution of each factor to productivity growth. The estimation procedures are also noted and the results are summarized in Table 2.

As shown in Table 2, over the 1961-72 period, productivity grew at an annual average rate of 2.64%. Total output grew at 2.22% annually while total input increased by only 0.46% annually. Approximately 25% of the estimated annual output growth rate was attributable to the accumulated effects of 14 years of research activities for the 1961-72 period. Inputs accounted for about 31% of such growth, while weather and other factors contributed more than 40%. From 1973 to 1980, total output exhibited a higher growth rate (2.9%) than in the earlier period. However, the rate of growth in productivity decreased 1.34% annually since a larger portion of output growth was attributed to increased utilization of inputs. Research and its supporting services also increased in importance in Canadian agricultural production during this period.

Some 27% of the growth in total output during the 1973-80 period was attributable to the cumulative efforts of research activities and technological development, compared with only about 25% a decade earlier. The contribution to output growth from other unspecified factors declined substantially. Over the entire period 1961-80, research and its supporting services were responsible for 26% of the annual output growth rate of 2.14%.

When the contribution of research and its supporting services to output growth is converted into contribution to productivity growth, they account for about 40% of the growth over the study period. Weather and all other unspecified factors account for about 60% of productivity growth. Although research and technology increased in importance over the 1973-80 period, the rate of productivity growth slowed substantially. The annual productivity growth rate declined from 2.64% for the 1961-72 period, to 1.34% for the 1973-80 period. Over this period, research and its supporting services accounted for between 36.8% during 1961-72 and 41.4% during 1973-80 of the observed productivity growth. This is consistent with yield trends for major grains. For example, wheat yield per hectare increased more than 24% between

TABLE 2 CONTRIBUTION TO PRODUCTION AND PRODUCTIVITY GROWTH BY FACTOR, CANADA (%)

	1961-72	1973-80	1961-80
Rates of growth (annual)[1]			
Productivity	2.64	1.34	1.66
Total output	2.22	2.90	2.14
Total input	−0.46	1.59	0.52
Contribution to output growth[2]			
Research and technology	25.2	27.6	26.2
Total input and education	31.5	33.1	33.6
Weather	9.1	8.7	9.0
All other sources[4]	34.2	30.6	31.2
Contribution to productivity growth[3]			
Research and technology	36.8	41.4	39.5
Weather	13.3	13.1	13.5
All other sources[4]	49.9	45.5	47.0

[1] Annual average growth rate is calculated by using a time trend equation and the mean value of the variable over the time period under study.
[2] Contribution to output growth by different factors is calculated by multiplying the value of each factor by the corresponding coefficients and then converting to a percentage basis. In the case of the research and technology variable, the distributed lag coefficients over 14 years are used.
[3] Contribution to productivity growth is calculated in terms of a residual approach, i.e., productivity growth is the net output growth (a shift in the production function). Thus, output growth due to increased utilization of inputs will not contribute to productivity growth. Accordingly, productivity growth attributable to each factor is calculated by allocating the estimated productivity growth rate in terms of all other factors except total inputs.
[4] All other sources are unspecified factors such as government policy and program, structural changes, and residual.

Source: Agriculture Canada.

1961-65 and 1971-75. From 1971-75 to 1981-82, however, the increase was only 17%. Similarly, the yield increase for barley was 28% and 22% respectively, during these periods (Table 1).

These results may indicate that the ability of agricultural research and technology to act as a catalyst for productivity growth is deteriorating. It must be noted, however, that early advances may have resulted from research and technological developments related to breed and variety research, while more recent advances may have been the result of research and technological developments relating to machinery and cropping practices. Thus, without some reorientation of agricultural research and its supporting services, Canadian agriculture

may soon be in the position of living off past technological breakthroughs.

RESEARCH ACTIVITIES AND PRODUCTIVITY GROWTH POTENTIAL

The ability of research to act as the driving force behind agricultural productivity growth has diminished, as has the rate of growth of operating expenditures on research and its supporting services. The level of these expenditures grew rapidly between 1945 and 1960 (8.0% annually) resulting in rapid productivity growth 10 to 15 years later. The rate at which research activity grew slowed to 5.97% annually over the 1961-72 period. As a result, productivity growth declined from 2.6% annually over the 1961-72 period to 1.34% annually during the 1973-80 period. By the latter period, operating expenditures on research and its supporting services grew at an annual rate of 2.38%, a significant drop from the rate experienced during the earlier period. Thus, a continued decline in operating expenditures on agricultural research and its supporting services could result in a decrease in productivity growth through this decade.

The situation can be expected to continue if federal operating expenditures on agricultural research are used as an indicator.[8] These expenditures in constant 1971 dollars grew at an annual rate of 5.44% over the 1961-72 period. From 1973 to 1980, the rate of growth decreased significantly to 1.79% (see Table 3 for actual expenditures). In the 1981-85 period, the rate of growth on these expenditures decreased further to 1.01% annually.

Agricultural research activities carried out by the federal government make up a major component of the national agricultural research effort. Given the dampening effect of the recent economic recession on the private sector, it is likely that growth in total agricultural research and its supporting services in Canada has also likely declined in recent years. Prospects for high productivity growth remain weak for the balance of this decade as the contribution of research and technology to productivity growth diminishes. The problem becomes more serious if research expenditures in other countries are also declining and if the opportunity to import new technology declines. Further declines in research activities and subsequent rates of productivity growth could weaken Canadian agriculture's competitiveness in international markets.

TABLE 3 FEDERAL OPERATING EXPENDITURE ON AGRICULTURAL RESEARCH, CANADA ($ MILLION)

Year	Current dollars	Constant dollars[1]
1961-62	21.17	29.2
1962-63	21.65	29.5
1963-64	21.73	28.9
1964-65	22.87	29.8
1965-66	24.78	31.3
1966-67	28.37	34.4
1967-68	30.51	37.0
1968-69	35.13	39.7
1969-70	37.32	40.3
1970-71	42.37	43.9
1971-72	46.39	46.4
1972-73	51.25	48.9
1973-74	59.27	52.4
1974-75	67.30	52.5
1975-76	78.60	54.7
1976-77	85.78	54.8
1977-78	98.62	58.1
1978-79	109.85	60.0
1979-80	114.91	57.5
1980-81	128.79	58.1
1981-82	170.31	68.5
1982-83	185.73	67.8
1983-84	210.83	73.0
1984-85	207.22	69.1

[1] Deflated using GNE implicit price deflator: total (1971 = 100)

Source: Public Accounts.

NOTES

[1] Fu Lai Tung and Greg Strain are economists in the Farm Finances and Resources Division of Agriculture Canada. The authors would like to thank Dr. Jim McKenzie of Agriculture Canada and other reviewers for their pertinent suggestions and constructive criticisms.

[2] The productivity changes are updated by Agriculture Canada, based on the methodology developed by G. Brinkman and B. Prentice, *Multifactor Productivity in Canadian Agriculture: An Analysis of Methodology and Performance, 1961-80* (Ottawa: Development Policy Directorate, Agriculture Canada, 1983).

[3] Lu, Y., P. Cline and L. Quance, *Prospects and Productivity Growth in U.S. Agriculture*, Economics, Statistics and Cooperative Service, United States Department of Agriculture, Agricultural Economic Report 435 (Washington: GPO, 1979).

[4] Since actual production data were used to measure productivity, weather, which significantly affects production, becomes an important factor in isolating the contribu-tion of research and technology to productivity growth.

[5] Brinkman, G., *An Analysis of Sources of Multifactor Productivity Growth in Canadian Agriculture, 1961 to 1980, with Projections to 2000* (Ottawa: Development Policy Directorate, Agriculture Canada, 1984).

[6] See Brinkman, *An Analysis of Sources*, or Lu, Cline and Quance, *Prospects for Productivity Growth.*

[7] The equation employed in this study is the estimated distributed lag equation (in log-log form) for changes in agricultural production with aggregate inputs adjusted for the impact of general education for Canada; see Brinkman, *An Analysis of Sources*, Table 3.6, p.47. The equation in short form is:

$$lnX = .0718\, lnW + .329\, lnFI + .268 \sum_{i=1}^{14} lnARS + e$$

where

W = weather index,

FI = aggregate quantity of inputs adjusted for general education, and

ARS = agricultural research and its supporting services.

[8] Federal operating expenditures on agricultural research alone are used to illustrate the possible effect on future productivity growth simply because updated data on agricultural research expenditure by provincial governments, agri-business firms and private individuals after 1981 are not available at this time.

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CONVERSION FACTORS

Metric units	Approximate conversion factors	Results in:
LINEAR		
millimetre (mm)	x 0.04	inch
centimetre (cm)	x 0.39	inch
metre (m)	x 3.28	feet
kilometre (km)	x 0.62	mile
AREA		
square centimetre (cm^2)	x 0.15	square inch
square metre (m^2)	x 1.2	square yard
square kilometre (km^2)	x 0.39	square mile
hectare (ha)	x 2.5	acres
VOLUME		
cubic centimetre (cm^3)	x 0.06	cubic inch
cubic metre (m^3)	x 35.31	cubic feet
	x 1.31	cubic yard
CAPACITY		
litre (L)	x 0.035	cubic feet
hectolitre (hL)	x 22	gallons
	x 2.5	bushels
WEIGHT		
gram (g)	x 0.04	oz avdp
kilogram (kg)	x 2.2	lb avdp
tonne (t)	x 1.1	short ton
AGRICULTURAL		
litres per hectare (L/ha)	x 0.089	gallons per acre
	x 0.357	quarts per acre
	x 0.71	pints per acre
millilitres per hectare (mL/ha)	x 0.014	fl. oz per acre
tonnes per hectare (t/ha)	x 0.45	tons per acre
kilograms per hectare (kg/ha)	x 0.89	lb per acre
grams per hectare (g/ha)	x 0.014	oz avdp per acre
plants per hectare (plants/ha)	x 0.405	plants per acre

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Contents

Canadian farm finance perspectives

Dr. B. Perkins[1]

By way of introduction to this special issue of *Canadian Farm Economics* on farm finance issues, this brief note attempts to highlight the economic events contributing to the current financial difficulties in agriculture, the nature and extent of those difficulties and the implications for government policy.

Canadian agriculture has developed into a sector of substantial small businesses that are highly integrated within the rest of the economy through markets for farm products, farm inputs and farm financing. Canadian monetary and fiscal policies are major determinants of farm performance and prosperity through their influence on interest rates, exchange rates, inflation and economic growth.

Deriving about half its market revenue from export sales, largely from grains and oilseeds, the sector is highly dependent on international markets and is vulnerable to the agricultural policies of other countries.

In the 1980s the farm sector has suffered a series of economic problems and a serious reversal in its economic prospects. Successive international market weaknesses, high interest rates and Prairie droughts have precipitated farm financial problems, but the overvaluation of farmland assets and the excessive debt financing that evolved in the 1970s have been major contributory factors. As a result, the earlier prosperity has given way to reduced cash flows for many farmers, to a rising incidence of debt-servicing difficulties, to major declines in farm equity values and, for some farmers, to financial failure.

A more detailed examination of these developments shows that:

- between 1975 and 1980, farm debt outstanding in Canada doubled, mainly because of low real interest rates, very favorable commodity market prospects, and rapidly rising land prices; debt servicing costs rose commensurately;
- in 1979 interest rates began to move up and continued to escalate, reaching a peak of more than 20% in 1981, and in real terms have remained high throughout the 1980s;
- grain prices reached record levels in 1981, contributing to financial difficulties for livestock feeders;
- internationally, the 1980s has been a period of reduced growth in demand for agricultural commodities, because of high interest rates, economic recession, foreign debt crises in many importing countries and self-sufficiency trends in others; meanwhile, the supply of agricultural commodities has continued to grow at much the same rate as during the 1970s;
- world commodity market developments together with high interest rates combined to precipitate a reassessment of future returns to investment in Canadian agriculture, especially in those regions most dependent on export markets;
- as a result, land prices declined after 1982, and the consequent decline in farm equity brought negative returns to agricultural investment (losses);
- thus, reduced cash flow, resulting from market weaknesses, high interest rates and declining equity values, led to sharp increases in farm financial difficulties.

The incidence of financial difficulties facing Canadian farmers varies greatly by commodity, by region and from one individual to another; moreover, the problems range in intensity from the reduced rates of return experienced by most farmers to the financial difficulties that for some farmers result in financial failure. At present the problems are concentrated in grain, oilseeds and certain other crops, such as tobacco. Supply-managed commodities (dairy, poultry, eggs) have remained relatively insulated, and red meat producers at present are enjoying very favorable product/feed margins.

Correspondingly, financial difficulties are most apparent in areas dependent on the affected crops, such as grain farms in the Prairies, especially those already in some difficulty because of droughts in recent years. Everywhere the intensity of difficulty varies with individual circumstance, ability and luck: those farmers with less debt are better able to withstand cash flow shortfalls; the better farm managers have taken measures to cope with actual or anticipated financial difficulties by production shifts, cost reduction measures, partial liquidation of assets and the like; but for many farmers in difficulty,

the principal cause has been bad timing because they began farming or expanded their businesses just before interest rates soared or before land prices fell.

Recent assessments by Agriculture Canada suggest that about 12% of Canadian farmers are experiencing varying degrees of financial difficulty, with about 6% in serious difficulty. These rates probably represent a threefold increase in the incidence of farm financial difficulty relative to the 1970s or early 1980s.[2] At that, the impact of successive farm economic problems has been reduced by government assistance under established "safety net" programs (stabilization, crop insurance, etc.) and through special initiatives (western drought compensation, Special Canadian Grains Program, etc.).

Direct payments to producers under government programs have more than tripled during the 1980s to $2.8 billion in 1986, and to a projected $3.7 billion in 1987. Such payments account for 14% of total farm cash receipts in 1986 and for 17% in 1987. Major financial assistance has also been provided through special loans totaling $3.5 billion, through the carrying of accounts in arrears and through other measures to help farmers in financial trouble.

While there have been several contributory factors, the underlying roots of Canadian farm economic problems lie in the worldwide subsidies, which have stimulated agricultural production above market requirements. Internationally, government production incentives, domestic market protectionism, commodity export subsidies and related trading practices have depressed international market prices below cost-recovery levels and have distorted commercial trade flows.

Short of a major and prolonged world crop shortfall or substantive international progress in curtailing subsidies, international market recovery is not expected before the 1990s. That recovery in turn is dependent on renewed demand growth, especially in the Third World, on major reductions in commodity stockpiles and on reduced production incentives. The political conditions associated with these conditions limit the grounds for optimism. Moreover, major technological changes in crop and livestock production point to further price pressures in the future.

The magnitude of the economic reversal facing Canadian agriculture is too great to be offset by government assistance. Indeed, present assistance levels are difficult to maintain given the size of fiscal deficits, the demands of other sectors and the duration of the international market downturn. Furthermore, the assistance provided by governments, in the main, is not targeted on individual financial difficulty but on broad market or production shortfalls.

Consequently, farm production and financing adjustments are occurring and can be expected over time to bring about major changes in Canadian agriculture. Land values will continue to decline until expected rates of return rise to those of alternative investments. Withdrawal of marginal land, expansion of summerfallowing, less intensive cropping and continuing low investment levels will result in declines in total output. Where possible, farmers will shift out of depressed commodity sectors, especially cash grains, into more buoyant enterprises such as livestock feeding. Supply management quota values will be bid up as farmers try to ensure themselves against market uncertainties. Increased liquidation of farm businesses will result in a greater concentration of asset ownership among established farmers. Financial management and equity base will increasingly be the prerequisite for survival and success.

The market orientation of these agricultural adjustments and of the government policies designed to assist the sector will depend critically on the international understandings and agreements reached on agricultural trade and on associated domestic policies. A continuation of prevailing policies among major agricultural trading countries will result in continuing financial difficulties for Canadian export-oriented commodities (despite large-scale government assistance), in progressive declines in farm output, and in some extension of the problems to other commodities through production shifts. International agricultural agreements to correct the situation will need to freeze or reduce production incentives, to rationalize supplies and to reform trade practices on a multilateral and multicommodity basis; such scenarios would provide very different prospects for Canadian agricultural adjustment.

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1 Dr. B. Perkins is Director General, Farm Development Policy Directorate, Agriculture Canada.

2 Comprehensive long-term indicators of farm financial difficulty are not available; the concept itself is subject to variable interpretation. Farm Credit Corporation loans provide one set of indicators: since the 1970s the number of accounts in arrears has more than doubled and the dollar amount in arrears has increased more than tenfold.

Financial performance indicators for the Canadian agriculture sector

S. Narayanan and A.P. Cloutier[1]

INTRODUCTION

In the past few years declining farm asset values, increased real interest rates, higher debt service load, dampened export demand, and weak world market prices have adversely affected the financial health of the Canadian agriculture sector and have taken their toll on many vulnerable farm businesses. Appropriate indicators of the financial performance of the farming industry are essential to the policy makers and farm leaders for assessing the financial health of the industry and for taking steps to ensure the survival of the farming industry.

Traditional farm income indicators such as net farm income do not seem to provide enough insight into the financial performance of the industry. They lump the current returns from a number of different resources such as management, unpaid family labor, and equity capital, whose level and composition are constantly changing, and they fail to recognize the economic returns in the form of capital gains or losses (Perkins 1985).

Farm sector balance sheet measures relating to debt and assets, e.g., debt to asset ratio, also fail to perfectly reflect the financial distress situation, although they serve as best indicators of serious financial problems over time (Harrington and Stam 1985). Furthermore, off-farm income is generally ignored in farm income indicators, although farm operators and their families are increasingly involved in generating supplementary nonfarm income which is accessible to farm business at least under situations of stress.

The procedures for deriving income from different resources (labor, management, assets and equity capital) and other balance sheet measures were formally developed by Melichar (1979, 1984). Since then, considerable debate has ensued over ways to improve the methodology in order to impute remunerations to management, unpaid family labor and residual allocation of returns to assets and equity.

This article presents a set of financial indicators for the Canadian agriculture as developed jointly by the authors in their research on assessing the financial performance of Canadian farming industry (Cloutier and MacMillan 1986, Narayanan 1986). The authors' research was primarily focused on improvements in methodology to develop a set of comprehensive indicators to adequately reflect the financial performance of the farm sector. In the following sections, a set of such financial indicators, their description and methodology, and the results for the 1970-85 period, including discussion, are presented.

DESCRIPTION AND METHODOLOGY

Income from assets and management

The income from assets and management is obtained by netting out from the total gross farm income augmented by farm rent[2] all the operating expenses excluding interest, depreciation charges, and income imputed to operator and unpaid family labor estimated as equivalent to number of hours, times the average hourly farm wage rate with room and board. This income measure represents the current return on ownership, control and management of farm capital. The average rate of return on assets and management is computed by dividing the above income by the value of farm assets. Any reduction in this rate is indicative of a decline in profitability of investment in agriculture.

Total return on assets

Total return on assets is calculated by adding the unrealized real capital gains (losses) on assets and the income from assets and management. Real capital gain (loss) on assets is defined as the change in the value of farm capital less net fixed capital formation (gross minus depreciation), the loss of purchasing power of all funds tied up in the farm assets[3] measured using the GNE deflator[4] for personal expenditures, and the investment in livestock. Investment in livestock is separately netted out because Statistics Canada excludes these data from capital formation statistics. The rate of return on assets

is derived by dividing the total returns as derived above by the total value of assets. This rate represents the potential profitability of investment in farm assets only as returns in the form of real capital gains not actually realized.

Total return on farm equity

Total return on farm equity is derived by subtracting paid interest charges from the total return on assets and adding real capital gains made on debt as a result of inflation. Real capital gain (loss) on debt represents the decrease (increase) in general purchasing power of funds owed and is estimated using the changes in the GNE deflator for personal expenditure. Rate of return on equity is derived by dividing the total return on farm equity by the total value of farm assets minus the (total) debt outstanding.

Profit margin

Profit margin is defined as the proportion of gross farm income that is residually allocated to the income from assets and management. As the name suggests, this margin measures the actual profitability of farming, as opposed to the rate of total returns on assets, which measures the potential profitability (before taxes in both cases).

Cost ratio on debt

This ratio is derived by dividing the total real cost of debt, which is equal to interest paid minus real capital gains on debt, by the total debt outstanding. This ratio indicates the relative expensiveness (cheapness) of borrowed capital.

Debt to asset ratio

The debt to asset ratio expresses the total of all borrowed funds as a proportion of the value of all capital assets. This simply indicates the relative indebtedness of farm firms and is considered as the best single available measure of the seriousness of current financial difficulties (Harrington and Stam 1985). It is also one of the measures of solvency; that is, it indicates the potential for restructuring the farm business through liquidation of some less productive assets.

Operating margin (cash flow)

This is a measure of cash income to the operation before family living expenses and principal repayments and is used in assessing the income-generating capacity of the farm business (Joseph and Reinsel 1986). This indicator is measured as the receipts from production and other sources (government payments, farm rental) less the operating expenses associated with production and all interest expenses (depreciation excluded). This measure can be used to assess debt principal servicing ability.

Interest coverage ratio

This is the ratio of income from the assets, labor and management to interest paid on farm debt. As the name implies, this ratio indicates the extent of the burden of interest on the farm business. However, this financial indicator is more suited to studying the longer-term debt burden, as investments in farm assets in the short term can be postponed, thus reducing the financial requirements and interest charges. In the long term, such investments become imperative if the business is to remain in operation.

Net operating margin (surplus/shortfall)

This is a measure of cash flow (surplus or shortfall) and is derived by subtracting the estimate of fixed minimum family living expenses and the estimated principal repayments from the operating margin. Depending on whether this measure is positive or negative, the industry is identified as having a surplus or shortfall cash flow situation. In this derivation, principal repayments are estimated for medium- and long-term debt, as the short-term debt employed mainly for production expenses is accounted for under operating expenses. The minimum family living expenses are estimated by multiplying the average expenditure reported in the Rural Farm Family Consumption Survey by Statistics Canada, updated by using the Consumer Price Index, and the number of census farms interpolated for the intercensus years.

Family net operating margin

In this measure, the off-farm income of farmers is also included in deriving the net operating margin. Since farm family's off-farm income is available to supplement total net earnings or to cover temporary fund shortages, the inclusion of off-farm income is considered essential in assessing the susceptibility of the farm enterprises to adverse financial situations. In addition, if one is to consider family living

expenses in the farm cash flow analysis, the analysis would be consistent only if off-farm income is also included in the income stream.

In any case, off-farm income can be considered as a buffer to help farm businesses in times of adverse economic conditions. Difficulty, however, arises in obtaining proper estimates of off-farm income for the industry. In general, small or part-time farmers have much larger off-farm incomes and they represent a large portion of the farm population and small portion of production.

Individual differences also exist in off-farm incomes among farms with similar balance sheets. An estimate of family net operating margin (cash flow) surplus or shortfall is obtained by adding the estimated off-farm income to the net operating margin (cash flow) measure. At the industry level, consecutive downward changes in this measure should be interpreted as signaling serious problems at the farm level in an industry characterized by large debts and inflexible repayment installments. Farm level data are essential to specifically identify those sections of the industry facing cash flow shortfall problems.

ASSUMPTIONS AND LIMITATIONS

The assumptions by and large relate to the methodology of imputing returns to factors and to the procedures used in developing the indicators.

First, with no Canadian time series data for income from management, returns to management are usually imputed under various assumptions relating to the proportion of the hours of input by the family and by operator labor for management and to the applicable wage rate. The credibility of such assumptions are always subject to dispute. Cloutier and MacMillan (1986) discuss the arbitrariness and the doubtful nature of such assumptions. The present article therefore assumes that management income is indistinguishable from current returns on business assets, as is the case in many owner-operated enterprises, which is also in accordance with national income concepts. The theoretical reasons behind this assumption are related to the fact that access to basically unmarketed resources is obtained by defining their owners as residual claimants (Eswaran and Kotwal 1985). Second, in the absence of data series for investment in livestock capital, this is assumed to be equal to the additions to the inventory of cattle and hogs multiplied by the value per head of livestock. Third, it is assumed that the total off-farm income series for farm taxfilers as provided by the Revenue Canada, Taxfiler Statistics,[5] fairly represent the off-farm income for the agriculture industry.

As for limitations, the available Statistics Canada time series data on the value of farm assets do not include farm business financial assets (cash, relevant bonds, account receivable) and other assets such as quotas, feed and supplies.[6] In addition, the Revenue Canada Taxfiler Statistics (for off-farm income) exclude incorporated farmers and those farmers whose major source of gross income is not farming.

RESULTS

The results for the Canadian agriculture sector using the methodology presented above are shown in Figures 1 to 3, and in Tables 1 to 3. Published data from Statistics Canada and Revenue Canada are employed (see sources to Table 1).

Table 1 presents in constant terms the income, current and total returns and the rate of returns in Canadian agriculture for the 1970-85 period. It also outlines the steps in the calculation procedures.

As can be seen from the table, despite increasing farm interest costs due to higher farm debt, the rate of return on assets and management during the 1970-85 period fluctuated generally around 2% (barring the 1972-75 period), which is very similar to the long-term trend experienced since the early 1960s (Figure 1). In the 1981-85 period, high inflation rates during the early years have turned the current dollar capital gains into real capital losses. This trend is further accentuated by the decline in asset values in the subsequent years (Figure 2).

The magnitudes of the rate of real capital losses have been similar to the rate of losses registered between 1926 and 1955 (Figure 3). The effective rate of capital losses should be considered to be even smaller because financial assets, quota and so on are not included in the asset data, a limitation noted earlier.

TABLE 1 INCOME, RETURNS, RATES OF RETURN AND THE PROFIT MARGIN IN CANADIAN AGRICULTURE, 1970-85

Income and returns	1970	1971	1972	1973	1974	1975	1976	1977
				(million 1981 constant dollars)				
Total gross income + farm rental income (as defined by Statistics Canada)	10 855	11 619	12 408	16 691	17 567	18 439	17 010	15 884
Less wages paid to farm labor	690	721	733	872	858	950	954	992
Less other operating expenses (excluding interest)	4 880	5 334	5 673	6 609	7 247	7 350	7 350	7 317
Less depreciation charges	1 326	1 291	1 319	1 379	1 585	1 887	2 109	2 185
Subtotal: income from assets operators' labor and management	3 959	4 273	4 683	7 831	7 877	8 252	6 588	5 370
(Realized net farm income (as defined by Statistics Canada) = Total gross income - value of inventory changes - total operating expenses and depreciation charges)	2 955	3 006	4 287	5 530	6 763	6 478	4 796	3 605
Less income imputed to operators and unpaid family labor	3 192	3 290	3 180	3 417	3 724	4 033	3 974	3 802
Subtotal: income from assets and management	767	983	1 503	4 424	4 153	4 219	2 615	1 565
Plus real capital gains on assets	−1 618	−1 455	2 165	5 166	5 045	4 150	4 815	1 954
Subtotal: total return on assets	−850	−472	3 688	9 580	9 198	8 370	7 430	3 509
Less interest paid	647	622	726	696	889	922	1 061	1 056
Plus real capital gains on debt	371	251	434	849	1 385	1 404	1 161	1 211
Total return on equity	−1 126	−843	3 376	9 733	9 694	8 852	7 530	3 664
				(percent)				
Rate of return on assets and management								
Income	1.3	1.8	2.6	6.7	5.5	5.1	2.9	1.6
Real capital gains	−2.8	−2.6	3.7	7.8	6.7	5.1	5.4	2.1
Total	−1.5	−0.8	6.2	14.5	12.3	10.2	8.3	3.7
Cost ratio on debt								
Interest charges	6.3	5.8	6.7	6.0	7.2	6.9	7.5	7.0
Real capital gains	3.6	2.4	4.0	7.3	11.3	10.5	8.2	8.1
Difference (real cost of debt)	2.7	3.4	2.7	−1.3	−4.1	−3.6	−0.7	−1.1
Interest coverage ratio	6.1	3.7	6.5	9.2	8.9	9.0	6.2	5.1
Rate of return on equity	−2.4	−1.9	7.0	17.8	15.5	12.9	10.0	4.6
Profit margin	7.1	8.5	12.1	26.4	23.6	22.9	15.4	9.7

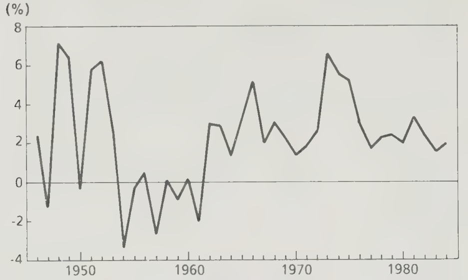
(continued)

TABLE 1 INCOME, RETURNS, RATES OF RETURN AND THE PROFIT MARGIN IN CANADIAN AGRICULTURE, 1970-85 (CONCLUDED)

Income and returns	1978	1979	1980	1981	1982	1983	1984	1985
				(million 1981 constant dollars)				
Total gross income + farm rental income (as defined by Statistics Canada)	17 357	18 653	18 435	20 398	17 792	16 285	16 659	16 651
Less wages paid to farm labor	982	1 015	1 020	1 073	1 050	1 061	1 058	1 069
Less other operating expenses (excluding interest)	7 841	8 522	8 885	9 082	8 525	8 365	8 413	8 191
Less depreciation charges	2 231	2 492	2 632	2 628	2 483	2 334	2 220	2 067
Subtotal: income from assets operators' labor and management	6 213	6 614	5 898	7 614	5 734	4 425	4 968	5 324
Realized net farm income (as defined by Statistics Canada) = Total gross income - value of inventory changes - total operating expenses and depreciation charges)	4 170	4 385	3 730	3 755	3 139	2 368	3 539	3 059
Less income imputed to operators and unpaid family labor	3 849	3 753	3 319	3 261	2 930	2 867	2 869	3 031
Subtotal: income from assets and management	2 364	2 861	2 579	4 353	2 804	1 558	2 099	2 293
Plus real capital gains on assets	7 374	10 127	8 902	−3 030	−12 118	−10 180	−7 788	−9 963
Subtotal: total return on assets	9 738	12 988	11 481	1 323	−9 314	−8 662	−5 689	−7 670
Less interest paid	1 244	1 647	1 796	2 424	2 046	1 589	1 620	1 452
Plus real capital gains on debt	1 234	1 622	1 899	2 127	1 945	1 051	768	707
Total return on equity	9 728	12 963	11 583	1 026	−9 415	−9 200	−6 541	−8 415
				(percent)				
Rate of return on assets and management								
Income	2.3	2.4	2.0	3.4	2.3	1.5	2.0	2.5
Real capital gains	7.1	8.6	6.8	−2.3	−10.2	−9.4	−7.5	−10.8
Total	9.4	11.0	8.8	1.0	−7.9	−7.9	−5.5	−8.3
Cost ratio on debt								
Interest charges	7.7	9.4	10.1	13.4	11.3	8.9	9.1	8.4
Real capital gains	7.6	9.3	10.7	11.7	10.9	5.8	4.3	4.1
Difference (real cost of debt)	0.1	0.1	−0.6	1.0	0.4	3.1	4.8	4.3
Interest coverage ratio	5.0	4.0	3.3	3.1	2.8	2.8	3.1	3.7
Rate of return on equity	11.1	12.9	10.3	0.9	−9.3	−10.1	−7.8	−11.2
Profit margin	13.6	15.3	14.0	21.3	15.8	9.6	12.6	13.8

Sources: Statistics Canada, Census of Agriculture, cat. nos. 96-902 to 96-911;
Statistics Canada, Farm Wages in Canada, cat. no. 21-002, and specially tabulated labor hours;
Statistics Canada, Fixed Capital Flows and Stocks, cat. no. 13-211;
Statistics Canada, Handbook of Agricultural Statistics;
Statistics Canada, Handbook of Farm Net Incomes;
Statistics Canada, System of National Accounts, cat. no 16-201.

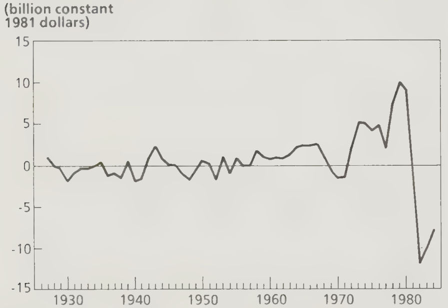
FIGURE 1 RATE OF INCOME FROM OWNERSHIP, CONTROL AND MANAGEMENT OF FARM CAPITAL, CANADA, 1946-84



Source: Cloutier and MacMillan (1986)

During the 1982-85 period, the rates of the total returns from assets (defined as the rates of return on income and capital gains) were negative because large (unincurred) negative capital gains (losses) more than off-set the income from assets and management. These large negative capital gains rates have seriously eroded the value of farm collateral, creating financial crises for many highly leveraged farmers.

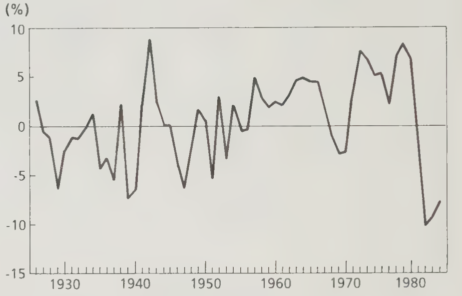
FIGURE 2 REAL CAPITAL GAINS ON FARM ASSETS, CANADA, 1926-84



Source: Cloutier and MacMillan (1986)

However, this phenomenon per se should not be taken as an index of a major financial problem since most farms still have enough equity to secure their short-term credit needs, and also since the profitability of farming in terms of profit margin (as explained earlier) for the sector still remained at a reasonably acceptable level. At the trough of the 1981-83 agricultural recession, the farm sector profit margin decreased to only about 9.6% (see Table 1 for 1983), which was higher than that in the preceding agricultural recessions in the late 1960s and early 1970s and in 1977. Besides, in the 1982-84 period, the farm sector's gross incomes in real terms were also relatively higher than those during all previous downturns.

FIGURE 3 RATE OF REAL CAPITAL GAINS ON FARM ASSETS, 1926-84



Source: Cloutier and MacMillan (1986)

For these reasons, aggregate farm income per se cannot be singled out as the primary source of the farm sector's financial problems. However, within the industry, the heavy debt burden of some farmers with very large debt service requirements would indeed have low profit margins because of their smaller cash flow, for example, beginning farmers in the Prairie Provinces, who are dependent on grain and livestock.

The total real cost of debt, which is the difference between interest charges and real capital gains on debt (Table 1), remained negative or very small during the 1972-82 period and then increased substantially during the 1983-85 period. This again is an indication of financial stress, since the real capital gains on debt during this period did not fully offset the interest charges, primarily because of lower inflation and higher real interest rates.

The interest coverage ratio, which measures the long-term burden of debt, has been on a steady decline since the 1950s. In the 1980-85 period, the average interest coverage ratio fell to less than half the average ratio for the 1970-79 period from 6.4% to 3.1% (Table 1). This clearly shows that the industry was experiencing

financial stress, primarily as a result of an increase in interest charges associated with minor reductions in income from all factors. Although the short-term decline in interest coverage ratios (as in the recent times) are attributable to commodity prices and interest rates, it is mainly the burden of debt that is chiefly responsible for the long-term decline in the ratio. In the early 1980s, the interest coverage ratios sagged to low levels similar to those during the depression years of the 1930s (see Cloutier and MacMillan 1986). This indicates that debt repayment is likely to be a growing source of financial stress.

Finally the rate of return on equity, which remained in high double-digit positive levels during the middle and late 1970s, suddenly took a plunge to negative double-digit levels as a result of large capital losses in the same period. This is yet another indication of the financial stress situation that the industry currently is undergoing.

The debt to asset ratios (Table 2) show a gradual decrease from 0.191 in 1971 to 0.136 in 1980. This fall of 28.8% can be attributed to the large capital appreciation, part of which was applied as collateral to secure more debt while the remainder went to enhance equity. However,

TABLE 2 DEBT TO ASSET RATIO IN CANADIAN AGRICULTURE

	Debt outstanding	Assets	Equity	Debt to asset ratio
	(million 1981 constant dollars)			
1970	11 571	62 629	51 558	0.184
1971	10 652	55 738	45 086	0.191
1972	10 849	58 855	48 006	0.184
1973	11 621	66 209	54 588	0.176
1974	12 271	74 828	62 557	0.163
1975	13 308	82 137	68 829	0.162
1976	14 237	89 655	75 418	0.159
1977	14 997	93 904	78 907	0.160
1978	16 235	103 767	87 532	0.156
1979	17 509	117 946	99 987	0.148
1980	17 737	130 774	113 037	0.136
1981	18 134	130 297	112 263	0.139
1982	18 087	118 743	100 656	0.151
1983	17 756	108 540	90 784	0.164
1984	17 511	101 499	83 988	0.175
1985	17 360	92 480	75 120	0.188

Source: Statistics Canada.

this ratio climbed steeply to approach the 1971 level of 0.188 during the next 5 years. This indicates the overall deterioration in the equity situation of the industry.

The rapid slide in the asset values, along with slow and diminishing rate of debt increase, has led to this rise in the debt to asset ratios for the industry as a whole. Although this may not reflect serious financial problem for the whole industry, since equity is still more than 80%, for the highly leveraged farmers with poor cash flow, this spells serious financial difficulty and nonviability.

The operating margin (cash flow) from farm business (Table 3) oscillated between \$6.2 and \$8.9 billion during the 1973-81 period, and fell drastically below \$6 billion during the following years. By 1983, the cash flow level fell 32.6% below the 1981 level. Even though the cash flow situation started to recover slowly thereafter, its 1985 level still remained 24% below the 1981 level. This relatively low cash flow level and its weak recovery rate, along with relatively large debts outstanding, also indicate the financial stress situation for the industry in the recent times.

This situation becomes even more clear if the net operating margin (surplus/shortfall) after principal repayments and minimum family living expenses is examined (Table 3). After 4 years of moderate surplus net operating margin followed by 5 years of moderate levels of shortfall, the industry experienced a continuous 4-year large net operating margin shortfall between 1982 and 1985, which was very similar to the experience of the 1970-73 period. Although the growth in the net operating margin deficit appears to be slowing down, the shortfall situation is likely to prevail at least until 1989 before turning positive. This apparent trend spells disaster to many highly leveraged farms.

Those farms generating reasonable levels of off-farm income would be in a better position to cushion or offset the shortfall and perhaps to generate a surplus cash flow. This can be seen from the surplus in family net operating margin (cash flow) after adding off-farm income for the family to the net operating margin (surplus/shortfall) for the industry as a whole (Table 3). It could be argued that only some part of the off-farm incomes contributed by operators and their family members alike could be accessible for farm family and business use. Even if we assume that only 30% to 40% of the

TABLE 3 CASH FLOW INDICATORS FOR CANADIAN AGRICULTURE, 1970-85

	Total gross receipts[1]	Total farm expenses[2]	Operating margin (cash flow)[3]	Estimated principal repayments[4]	Family living expenses[5]	Net operating margin[6] (surplus/ shortfall)	Off-farm income for the family[7]	Family net operating margin[8] (surplus/ shortfall)
	(million 1981 constant dollars)							
1970	10 556	6 217	4 343	279	5 411	−2 028	2 509	481
1971	11 352	6 677	4 675	256	5 568	−1 556	2 623	1 067
1972	12 136	7 132	5 004	321	5 828	−1 296	2 998	1 702
1973	16 337	3 177	8 160	421	5 753	2 153	3 612	5 765
1974	17 270	8 994	8 276	513	6 216	1 580	4 590	6 170
1975	18 175	9 222	8 953	607	5 662	2 684	5 325	8 000
1976	16 707	9 365	7 342	750	6 263	329	5 728	6 057
1977	15 616	9 365	6 251	909	6 277	−935	5 868	4 933
1978	17 061	10 067	6 994	1 010	6 003	−19	6 403	6 384
1979	18 334	11 184	7 150	1 234	5 917	−31	7 114	7 083
1980	18 138	11 701	6 437	1 373	5 828	−764	7 926	7 162
1981	20 124	12 579	7 545	1 528	5 782	235	8 910	9 145
1982	17 565	11 624	5 941	1 650	5 743	−1 452	8 667	7 215
1983	16 074	11 015	5 059	1 649	5 725	−2 315	7 732	5 417
1984	16 443	11 091	5 352	1 698	5 706	−2 052	8 380	6 328
1985	16 453	10 712	5 741	1 674	5 184	−1 617	N.A.	N.A.

1 Total gross receipts = total gross income plus farm rental income less income-in-kind
2 Total farm expenses excluding depreciation
3 Operating margin (cash flow) = total gross income + farm rental income - total expenses including interest payments and excluding depreciation
4 Principal repayments include repayments for medium- and long-term debt, assuming 5-year and 20-year terms respectively
5 Family living expenses estimated on the basis of all Consumption Expenditure Survey for rural families by Statistics Canada and the number of census farms interpolated for intercensus years
6 Net operating margin (surplus/shortfall) = operating margin from business after principal repayment and minimum family expenses
7 Off-farm income = off-farm income earned by operators and farm family members, as computed from taxfiler data (Revenue Canada Taxation Statistics)
8 Family net operating margin (shortfall/surplus) = net operating margin (surplus/shortfall) + off-farm income

off-farm incomes are accessible for farm business use, still the industry as a whole appears to be financially safe because of the realized surplus family net operating margin (cash flow). This is not to conclude, however, that no individual farm will have family net operating margin (cash flow) shortfalls. Many (large) farms with farm incomes greatly exceeding off-farm incomes can still experience family net cash flow shortfalls even after including their off-farm incomes. Under such situations, the possibility of restructuring the business with the remaining equity in order to eliminate or reduce the amount of the shortfall is still open.

SUMMARY

This article presents a set of indicators relating to the financial health of the Canadian agriculture sector. A single indicator by itself is insufficient to adequately reflect the financial situation (stress or soundness) of the industry, although a combination of various measures outlined in this article can be used effectively to monitor the financial well-being of the industry.

These industry-level indicators behave in a very volatile fashion, as do data on agriculture production and prices, and are insufficient to identify the source of the financial difficulties.

This is especially true when a small portion of the sector experiences serious problems. However, the trend and relative changes in these indicators over time provide a useful indication of the problem within the industry for further investigation. Cross-sectional survey information is essential to permit multiindicator analysis by farm subsectors and to clearly identify the sectors of the farm industry that are experiencing financial hardship as well as the sources of these difficulties.

The results of the analyses of the financial indicators over the 1970-85 period as presented here seem to confirm the financial stress situation of the Canadian agriculture industry in recent years in terms of:

- low and negative rates of return on assets and management and on equity; negative rates of return on capital gains, which indicate erosion in asset and collateral values;
- low interest coverage ratios, increased real costs of debt and higher debt to asset ratios, which indicate a severe burden of debt;
- declining net operating margins (shortfalls); and
- diminishing family net operating margins (surpluses)

However, the profit margin as an index of actual farm profitability remained reasonably acceptable, relative to its level in previous recessions in agriculture. This indicates that aggregate farm income per se is not the cause of the industry's financial problems. The article does not present any forecast of the future financial situation, as the analysis was confined to the ex post (historical) period.

FOOTNOTES

[1] Shankar Narayanan is a research economist at Agriculture Canada and A. Pierre Cloutier is a research economist at the Economic Council of Canada. No senior authorship is assigned. The authors are grateful to Eric Johannsen, Fu Lai Tung, Wayne Jones, John Caldwell and William McBride of Agriculture Canada and to George Brinkman of the University of Guelph for their valuable comments and suggestions.

[2] Farm rent is an income from farm assets and as such must be included in the total gross farm income. Total gross farm income is equal to farm cash receipts plus income-in-kind plus change in the value of the inventory. When operating expenses are netted out, this cancels the farm rental incomes earned by owners of assets and therefore they are not present in the residual income.

[3] Conceptually, the cost of land improvements should be subtracted from the change in the value of farm capital. Since only arbitrary estimates were available, we refrained from considering them. These were of a relatively small scale, amounting to around one half of one percent of the value of farmland and buildings.

[4] The GNE deflator is preferred to the Consumer Price Index because the latter has fixed weights and overstates the rate of inflation during periods of rising interest rates (Melichar 1984).

[5] Under the Revenue Canada definition, a farm taxfiler is an individual who reported some income from farming on the tax return.

[6] These omitted assets have been estimated to represent 14% of the 1984 farm assets in Canada (FCC 1984).

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Sensitivity analysis of farm income to changes in the economic environment

F.L. Tung[1]

INTRODUCTION

Farmers in Canada have experienced a very significant change in the economic environment over the past two decades. During the 1970s, farmers typically experienced strong commodity prices and marketings, rapidly rising land values, and a growth-oriented agriculture. Under this economic environment, farmers enjoyed high farm incomes. As a result, realized net farm income in constant 1981 dollars (GNE deflator) was expanded to reach a peak of more than $6.7 billion in 1974 and was maintained at more than $3.5 billion during the balance of the 1970s (Figure 1).

FIGURE 1 REALIZED NET FARM INCOME, CANADA, 1971-85

With the beginning of the 1980s, however, this prosperous economic environment weakened substantially. Many farmers faced declining commodity prices, increased market uncertainty, high real interest rates, fluctuating exchange rates and falling land prices. The changing economic environment of Canadian agriculture has strongly affected Canadian farmers during the past six years and it will continue to affect Canadian farmers throughout the remainder of the 1980s. Realized net farm income in constant 1981 dollars dropped below the 1971 level in 1983 and has fluctuated around the $3.5 billion level despite a substantial increase in direct program payments.

This situation could have significant implications for the viability and future growth potential of the Canadian agricultural industry. The purpose of this article therefore is to test the sensitivity of medium-term farm income to changes in the economic environment and in policy variables in order to give a better understanding of the basis of recovery.

ALTERNATIVE SENSITIVITY SCENARIOS

Farm income is affected by economic factors in the environment that determine prices and marketing or production of different commodities. Therefore the sensitivity is analyzed in terms of:

- prices and marketing or production of different commodities, and
- receipts, expenses and income.

Such analysis requires a highly sophisticated model in order to capture all interactions among factors to be analyzed. Chase Econometrics' Canadian Agricultural Model was employed for this analysis because it not only allows one to analyze commodity price and marketing or production responses to changes in exogenous variables (i.e., economic factors), but also allows one to simulate the effects on receipts, expenses and income.[2]

Formation of alternative scenarios is based on economic factors that are important to farm income but are uncertain in the future. Seven economic factors considered to be the major factors affecting farm income are analyzed. They are:

- interest rate,
- exchange rate,
- inflation rate,
- grain prices,
- livestock prices,
- grain export, and
- livestock export.

The analysis focuses on the sensitivity of medium-term (1985-90) farm income prospects to changes in each variable so that a better understanding of the basis of recovery can be achieved.

It should be noted that the sensitivity analysis employed in this study is a partial equilibrium analysis and does not take into account any interacting relationships among factors except those factors specified in the model. This may underestimate the full impact of change in one economic variable on farm income, but it should be sufficient to indicate its sensitivity to changes in farm income. Assumptions and data employed to form these alternative scenarios are discussed below.

Scenario 1: 10% higher interest rate

Farm income and farm financial prospects are highly dependent on interest rates. Over the past five years, high interest rates have exacerbated financial difficulties facing financially vulnerable farmers. To test the sensitivity of farm income prospects to interest rate change, all interest rate variables are increased by 10% in all periods throughout the study period. The model includes two interest rate variables: the prime rate and the mortgage rate. The interest rate assumptions for the baseline solution and the changes imposed to determine the sensitivity of higher interest rates are summarized in Table 1.

TABLE 1 DATA FOR INTEREST RATE SCENARIO

	1985	1986	1987	1988	1989	1990
	(%)					
Baseline						
Prime rate	10.52	10.45	10.11	9.50	8.81	8.50
Mortgage rate	12.11	11.62	11.52	11.32	10.19	9.04
Interest rate sensitivity						
Prime rate	10.52	11.50	11.12	10.45	9.69	9.34
Mortgage rate	12.11	12.78	12.68	12.45	11.21	9.94

Scenario 2: 10% stronger Canadian dollar (exchange rate)

The farm price of Canadian agricultural commodities and hence farm income are closely tied to the world supply and demand situation because Canadian farmers export a major portion of their production. Because most commodity exports are priced in U.S. currency and because the U.S. market dominates the export market, the value of the Canadian dollar relative to the U.S. dollar is an important determinant of Canadian farm prices.

To analyze the effect of a stronger Canadian dollar on farm income, the Canada-U.S. dollar exchange rate is reduced by 10% in each year of the study period while leaving interest rate and all other variables constant (Table 2).

TABLE 2 DATA FOR EXCHANGE RATE SCENARIO

	1985	1986	1987	1988	1989	1990
	(Can $/U.S. $)					
Baseline	1.36	1.34	1.33	1.33	1.34	1.33
Exchange rate sensitivity	1.36	1.21	1.19	1.20	1.20	1.20

Scenario 3: 10% higher inflation rate

The impact of inflation on the Canadian agricultural sector depends on the source of the general inflationary tendency. Given the current world commodity surplus, it is unlikely that a major contribution to higher inflation would come from food prices. To evaluate the impact of higher inflation on the Canadian agricultural sector, the consumer price index assumption is increased by 10% while holding all other macroeconomic assumptions fixed.

Scenario 4: 10% lower grain prices

Throughout history, commodity prices have experienced periods of sharp increases and sharp declines as supply and demand conditions have fluctuated. The current supply and demand situation, coupled with the provisions of the 1985 U.S. Farm Bill, suggests that we are about to experience a period of sharply lower crop prices over the next 2 to 3 years. The obvious impact of lower grain prices will be lower crop cash receipts, other things being equal. As a result of shifts in relative prices as well as lower prices, production adjustments will occur in the Canadian agricultural sector.

TABLE 3 DATA FOR LOWER GRAIN PRICES

	1985-86	1986-87	1987-88	1988-89	1989-90	1990-91
			(U.S. $/bu)			
Baseline						
Wheat price, 1 HRW, Kansas City	3.17	3.02	2.99	3.31	3.55	3.77
Corn price, 2 yellow, Omaha	2.38	2.32	2.20	2.41	2.55	2.80
Soybean price, 1 yellow, north central Illinois	5.19	5.54	5.01	5.30	5.82	6.24
Crop price sensitivity						
Wheat price, 1 HRW, Kansas City	3.17	2.72	2.69	2.98	3.19	3.39
Corn price, 2 yellow, Omaha	2.38	2.09	1.98	2.17	2.30	2.52
Soybean price 1 yellow, north central Illinois	5.19	4.98	4.52	4.78	5.24	5.62

To test the sensitivity of lower grain prices, the U.S. grain price assumptions are reduced by 10% annually over the forecast period, 1986-90, (Table 3). This approach enables a test of how the U.S. price change affects the Canadian agricultural sector.

Scenario 5: 10% lower livestock prices

Lower livestock prices, with all other factors remaining unchanged, reduce profitability in the livestock sector, except for the supply-managed industries. Therefore, producers would be expected to adjust production downward to reflect poorer prices and hence farm income.

TABLE 4 DATA FOR LOWER LIVESTOCK PRICES

	1985	1986	1987	1988	1989	1990
Baseline						
Steer prices, choice Omaha (U.S.$/cwt)	58.0	62.9	61.4	64.9	66.5	69.5
Barrows and gilts, Omaha (U.S.$/cwt)	45.2	48.8	46.7	45.1	47.5	51.8
Gross target return, milk (Can $/hL)	46.3	48.3	50.0	52.3	54.8	57.1
Broilers, Toronto, 4 pounds and under (¢/pound)	49.5	48.3	48.7	52.0	55.9	59.9
Turkeys, Toronto, heavy (¢/pound)	65.6	66.5	70.2	76.2	78.5	84.0
Eggs, Toronto farm price (¢/dozen)	99.5	97.6	100.6	99.0	101.5	106.6
Livestock sensitivity						
Steer prices, choice Omaha (U.S.$/cwt)	58.0	56.6	55.3	58.4	59.9	62.5
Barrows and gilts, Omaha (U.S.$/cwt)	45.2	43.9	42.1	40.6	42.7	46.6
Gross target return, milk (Can $/hL)	44.0	43.5	45.0	47.1	49.3	54.3
Broilers, Toronto 4 pounds and under (¢/pound)	49.5	43.5	43.8	46.8	50.3	53.9
Turkeys, Toronto, heavy (¢/pound)	65.6	59.8	63.2	68.6	70.7	75.8
Eggs, Toronto farm price (¢/dozen)	99.5	87.9	90.6	89.1	91.3	95.9

For this sensitivity analysis, livestock slaughter prices are reduced by 10% for all livestock sectors. In the dairy sector, the gross target return is reduced by 10%. To achieve the price reduction, U.S. slaughter prices of cattle and hogs are reduced by 10%, because Canadian prices are largely determined in the larger U.S. markets. The changes made to the baseline solution are listed in Table 4.

Scenario 6: 10% reduction in grain exports

In the late 1960s and early 1970s, Canada experienced a reduction in wheat exports, but not a corresponding reduction in production. As a result, inventories of wheat accumulated and were built to excessive levels. This led to the LIFT (Lower Inventories For Tomorrow) program, which sharply reduced plantings in an attempt to reduce inventories. Despite the buildup of inventories, wheat prices in Canada remained competitive relative to U.S. wheat prices.

To test the sensitivity of the impact of exports on the Canadian agricultural sector, all grain exports (wheat, barley, oats and rapeseed) are assumed to fall by 10% from the most likely scenario (baseline solution) in each year over the period studied (Table 5).

Scenario 7: 10% reduction in livestock exports

To test the sensitivity of the farm sector to reduced livestock trade, the level of exports of both live animals and animal products, except for supply-managed commodities, is reduced by 10% from the baseline forecast. Because limited quantities of supply-managed livestock and livestock products are exported, their impact would be minimal. Thus only beef, pork, cattle and hogs are considered in this sensitivity analysis, (Table 6).

TABLE 5 DATA FOR REDUCED GRAIN EXPORTS

	1985-86	1986-87	1987-88	1988-89	1989-90	1990-91
				(Mt)		
Baseline						
Wheat	17.70	20.06	21.10	21.81	22.75	23.56
Barley	3.80	5.55	5.80	6.04	6.13	6.65
Oats	0.04	0.03	0.06	0.08	0.08	0.12
Rapeseed	1.46	1.87	1.98	2.08	2.13	2.24
Export sensitivity						
Wheat	15.16	18.05	18.99	19.63	20.48	21.20
Barley	3.50	5.00	5.29	5.44	5.52	5.98
Oats	0.02	0.03	0.05	0.07	0.07	0.11
Rapeseed	1.55	1.68	1.78	1.87	1.92	2.02

TABLE 6 DATA FOR REDUCED LIVESTOCK EXPORTS

	1985	1986	1987	1988	1989	1990
				(million pounds)		
Baseline						
Beef, net exports, U.S.	161.5	131.5	111.1	106.3	171.7	169.7
Pork, net trade	376.2	458.4	376.5	237.4	300.9	369.0
Hog, net trade	1137.9	335.3	376.1	696.1	875.4	896.1
Export sensitivity						
Beef, net exports, U.S.	161.5	118.3	100.0	95.7	154.5	152.7
Pork, net exports	376.2	412.5	338.8	213.7	270.8	332.1
Hog, net trade	1137.9	319.8	338.5	626.5	787.9	806.5

RESULTS OF THE SENSITIVITY ANALYSIS

As indicated earlier, sensitivity is analyzed in terms of their relative impact on prices and production of different commodities and on receipts, expenses and income. The impact is calculated as the difference between the most likely case and alternative scenarios. The results are highlighted below.

Impacts on prices and production

Different scenarios have different impacts on prices and production. In general, a stronger Canadian dollar has the most significant effect on commodity prices and hence on production. Conversely, increased interest rates have the least effect. The impact on production is summarized in Table 7.

Scenario 1: Higher interest rate – Higher interest rates will have only marginal effects on commodity prices and production for both livestock and crops.

Scenario 2: Stronger Canadian dollar – A stronger Canadian dollar tends to decrease farm prices, if all other factors remain unchanged; that is, if the inflation rate remains the same as in the baseline situation and so on. A stronger Canadian dollar also causes the prices of Canadian-produced commodities to increase in terms of the currencies of importing countries. Thus export demand declines and Canadian prices are forced to fall.

A 10% stronger Canadian dollar decreases domestic grain prices by 7% to 12%. Larger reductions occur in early years when production remains relatively high. The impact becomes moderate when production adjustments are made in later stages to reduce inventories relative to the baseline inventory. A 10% stronger Canadian dollar decreases domestic livestock

TABLE 7 IMPACT OF ALTERNATIVE ECONOMIC SCENARIOS ON PRODUCTION, 1986-90 AVERAGE

	Most likely case	Changes from most likely case (baseline solution)						
		Interest rate	Exchange rate	CPI	Grain prices	Livestock prices	Grain export	Livestock export
	(volume)	(% change)						
Livestock production								
Cattle slaughter (000 head)								
Canada	2 870	+0.80	+0.24	–2.30	+0.77	–1.32	0.00	+0.59
East	1 158	+2.42	–0.17	–5.86	+0.95	–2.76	–0.17	+0.17
West	1 712	–0.30	+0.50	–0.23	+0.64	–0.40	+0.10	+0.30
Hog slaughter (000 head)								
Canada	14 592	–1.24	–0.94	–1.52	+1.12	–2.55	+0.09	–0.07
East	9 721	–1.79	–1.68	–1.32	+0.40	–2.48	–0.04	–0.12
West	4 871	–0.14	+0.50	–1.92	+2.57	–2.71	+0.30	0.00
Broilers, Canada (million pounds)	1 044	0.00	+0.90	+1.45	–1.30	–3.00	–0.20	0.00
Dairy, milk shipments, Canada (MhL)	74.6	0.00	+0.80	+0.40	+0.40	–0.70	0.00	0.00
Crop production, Canada								
Wheat (Mt)	28.86	0.00	–2.70	–1.94	–2.91	+0.50	–6.13	0.00
Barley (Mt)	14.94	0.00	–5.15	–0.93	–4.42	0.00	–4.41	0.00
Rapeseed (Mt)	3.93	+0.25	0.00	–0.76	–0.50	+4.32	–1.00	+0.25
Flaxseed (Mt)	0.82	+1.20	–1.20	–2.43	–3.65	+9.75	+12.20	+1.20
Corn (Mt)	7.03	+0.14	–3.00	0.00	–3.69	+2.42	+0.70	+0.14
Soybeans (Mt)	1.09	+0.90	–2.83	+0.70	–1.83	+0.90	0.00	0.00

prices by 9% to 10%. Lower prices reduce profitability and in turn cause reduced growth in livestock production relative to the baseline solution.

Scenario 3: Higher inflation rate – Higher inflation means lower consumer real income and reduced domestic demand for agricultural products, especially for meat and poultry items. Thus livestock prices, for cattle and hogs in particular, decline by 3% to 5% relative to the baseline solution, resulting in a reduction in production of 1% to 3% over the 5-year forecast period. In the supply-managed industries where farm prices are in part determined by the general inflation rate, higher inflation increases farm prices, but lower consumer real income allows only a marginal increase in production. In the crop sector, general inflation has little impact on grain prices, because they are determined in international markets. However, it has a significant impact on special crop prices and production since these commodities are consumed domestically.

Scenario 4: Lower grain prices – Lower grain prices reduce profitability for crop production while increasing profitability in livestock enterprises. Thus some decline in crop production occurs, while livestock production increases. Given the fixed investments associated with crop production, lower grain prices tend to have little impact on decisions regarding area planted as long as total operating costs do not exceed revenues. Such is the case with a 10% reduction in grain prices. The major adjustments are allocational; that is, cash crops such as wheat, rapeseed, and flaxseed area increase initially by 1% to 2%, then decline by 1% to 7% from their baseline values in 1989-90 and 1990-91. This is primarily due to their higher profitability relative to feedgrains in the baseline solution. Feedgrains such as barley, oats and corn decline by 3% on average initially and remain 2% to 7% below their baseline results throughout the study period. Over the period, hog production increases marginally by 1% to 1.5%.

Scenario 5: Lower livestock prices – A 10% reduction in live cattle prices results in beef cattle inventory reductions of 3% to 4% by the end of 5 years. Short-term response is much less; the reduction is zero to 1% after 2 to 3 years. For hogs, the production response is much quicker as a result of a shorter production cycle. The 10% price reduction results in a short-term reduction in slaughter amounting to 2% to 2.5% and inventories drop by nearly 6% at the end of the 5-year period. Growth in broiler production falls from 5.3% to 4.4% annually.

Scenario 6: Reduced grain exports – The general outcome is to increase inventories and to reduce area planted and production of major grains. Grain prices generally decline by 1% to 3% relative to the baseline solution. Somewhat lower prices result in increased carry-over stock and domestic consumption, but not by as much as the historical trend does. As a result, inventories generally accumulate at levels 20% to 40% above their baseline values by the end of the study period. Since grain prices decline only marginally, the livestock sector response is not significant, although there is a slight increase in animal populations.

Scenario 7: Reduced livestock exports – Generally reducing livestock exports in the short run increases total meat supplies for domestic consumption. Thus lower livestock prices result, and livestock production eventually declines. Live hog and pork exports account for a much larger share of total hog and pork production than do cattle and beef exports as a share of total production. Therefore the adjustments in the hog sector are greater than those in the cattle sector. Live cattle prices in Toronto and Calgary decline by about 0.25% to 0.50% annually. Live hog prices in Toronto and Edmonton decline by 1% to 2% annually. Cattle slaughter increases marginally, while cattle inventories decline marginally. The impact of the marginal price declines are insignificant for cattle production. The 1% to 2% decline in hog prices causes a moderate reduction in hog production. Thus total hog inventories decline from 0.1% to 0.2% in 1986 to 1.0% to 1.2% by 1990 from their baseline values. The regional impacts are very similar to the national impacts.

Impacts on receipts, expenses and income

The relative impacts of alternative scenarios on receipts, expenses and income are summarized in Table 8. The impacts highlighted below are the 5-year average effects.

Scenario 1: Higher interest rates – The most significant impact is in debt servicing requirements. Higher interest rates tend to increase interest expenses in the short run, because debt is

TABLE 8 IMPACT OF ALTERNATIVE ECONOMIC SCENARIOS ON RECEIPTS, EXPENSES AND INCOME, 1986-90 AVERAGE

	Most likely case	Changes from most likely case (baseline solution)						
		Interest rate	Exchange rate	CPI	Grain prices	Livestock prices	Grain export	Livestock export
	($ million)				(% change)			
Receipts								
Livestock receipts								
Canada	10 486	-0.20	-6.50	-1.60	0.00	-10.00	+0.08	-0.50
East	6 483	-0.30	-5.80	-0.50	-0.20	-9.20	0.00	-0.50
West	4 003	0.00	-7.90	-3.25	+0.40	-11.20	+0.17	-0.50
Crop receipts								
Canada	10 002	-0.03	-8.20	+2.56	-6.60	0.00	-4.40	0.00
East	2 792	-0.10	-3.90	+5.80	-3.60	-0.40	+0.40	0.00
West	7 210	-0.20	-9.90	+1.29	-7.70	0.00	-6.27	0.00
Total cash receipts								
Canada	20 488	-0.16	-7.40	+0.50	-3.10	-5.10	-2.10	-0.30
East	9 275	-0.20	-5.20	+1.40	-1.24	-6.30	+0.13	-0.38
West	11 213	-0.10	-13.50	+0.30	-4.81	-4.00	-3.80	-0.20
Expenses, Canada								
Total operating expenses	14 686	+1.70	-3.30	+4.20	-0.70	-2.20	-0.60	-0.10
Depreciation charges	3 178	-5.66	-7.70	+0.91	-6.60	-5.60	-6.40	-5.60
Total operating expenses and Depreciation	17 864	+0.40	-4.10	+3.30	-1.70	-2.90	-1.60	-1.10
Income, Canada								
Realized net farm income	3 845	-7.30	-25.30	-16.50	-13.60	-18.60	-8.40	-1.10

difficult to retire, especially during periods of low income. Given the expected low level of income for the remainder of the decade, it is unlikely that farm debt will decline appreciably. Farmers will have to continue to refinance shorter-term for longer-term debt and to increase total outstanding debt, as a 10% increase in interest rates indicates an 11% to 13% increase in interest payments on indebtedness. Other input prices increase, but utilization of these inputs decreases, resulting in a marginal reduction in other operating expenses. Realized net farm income is impacted mainly through the higher interest payments and marginal reduction in other operating expenses. At a relatively low income level, a 10% increase in interest rates reduces realized net farm income by about 7%.

Scenario 2: Stronger Canadian dollar — A 10% stronger Canadian dollar reduces total farm operating expenses by about 3% to 5% from the most likely (baseline) case over the study period. A sharp drop in cash receipts, especially in the West where the drop is about 7% annually, results. Thus, a 10% stronger Canadian dollar causes a 20% to 30% drop in realized net farm income.

Scenario 3: Higher inflation rate — Total livestock receipts decline marginally as a result of reduced receipts from cattle and hogs, despite a marginal increase in receipts from poultry, eggs and dairy products. Higher inflation has little effect on grain prices, but it has a moderate effect on special crop prices. As a result, crop receipts increase marginally. Overall, 10% higher inflation increases operating expenses by approximately 4%. Realized net farm income drops by about 16% annually over the forecast period.

Scenario 4: Lower grain prices — A 10% decrease in grain prices results in a 2% drop in grain receipts initially and in a further 9% drop by the end of the study period. This is an average annual drop in crop receipts of about 6% over the study period. Because the decline in total area planted is only marginal, total operating expenses decline by less than 1% throughout the study period. Lower grain prices encourage livestock production in the West; thus livestock receipts increase marginally. Realized net farm income initially decreases by only 3%, but in the last 4 years of the study period it declines by between 11% and 19%. On average, realized net farm income declines by more than 13% annually.

Scenario 5: Lower livestock prices — Livestock receipts decline by 9% to 10% over the 5-year forecast period in response to 10% lower livestock prices. Farm operating expenses decline by approximately 2% annually as a result of a moderate reduction in livestock production. Realized net farm income decreases by 15% to 20% by the end of the forecast period, resulting on average in an annual decline of about 18%.

Scenario 6: Reduced grain exports — Reduced plantings as a result of reduced grain exports reduces operating input requirements; therefore total operating expenses decline by 0.5% to 0.8% annually. Crop cash receipts decrease by between 3% and 5% over the period as the farm sector responds to lower crop prices and exports. Realized net farm income could decline by 8% annually during the study period as a result of a large drop in crop receipts relative to the drop in operating expenses.

Scenario 7: Reduced livestock exports — Reduced livestock production, induced by reduced livestock exports, results in a reduction of approximately 1% in total operating expenses and depreciation charges annually. Livestock receipts decline by 0.5% to 0.6% annually throughout the study period in both the East and the West. Realized net farm income declines by about 1% annually throughout the forecast period; the impact is therefore minimal.

SUMMARY OF RESULTS

The relative impacts of alternative scenarios on production and income are summarized in Tables 7 and 8. From these tables and the highlights discussed above, the following observations emerge.

Production and income response is more sensitive to price change than to demand change, especially export demand. This suggests that farm financial prospects are largely determined by the prospects for commodity prices, especially livestock prices, because these price changes are expected to have larger income effects than grain prices have.

All three macro variables, including interest rate, exchange rate and general inflation (CPI), have significant effects on Canadian agriculture. Exchange rates have the most significant effect on farm income, because about 50% of cash receipts are obtained from export markets, followed by general inflation and interest rates. This suggests that future income derived from the agricultural sector is heavily dependent on general economic policies and programs. Thus any farm income support programs should incorporate macroeconomic policies.

In almost all cases the impact on farm income is through a reduction in cash receipts; the exception is general inflation, which affects both expenses and receipts. Thus any farm income support program could be achieved through prices and through production control mechanisms.

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[2] These empirical analyses were carried out directly by Wharton Econometrics through contract arrangements. Comments and suggestions to form alternative scenarios were provided by Dr. Tom Tice of Wharton Econometrics and are greatly appreciated.

Financial arrangements of new farm entrants in the early 1980s

R.M. Josephson and J.B. Watt[1]

INTRODUCTION

Developments in agriculture during the past few years have resulted in hardships for existing farmers and in difficulties for entering farmers. Earlier studies by Hare (1946), Driver (1961) and Boehlje and Thomas (1974) indicate that hardships for new entrants have always been prevalent, at least to a degree.

The new entrants of the early 1980s, however, faced a most troublesome phenomenon. Inflation and good economic conditions had driven up capital requirements for farm assets during the mid to late 1970s. This condition had not gone away even though prospects for continuing farm prosperity were diminishing rapidly as the 1980s began.

During 1984, nearly 400 new farm entrants in Manitoba were surveyed for a study to obtain information about how new farmers managed to start farming during this time period. The study attempted to learn about resource requirements of these new entrants and how they obtained the necessary capital. It examined the source of borrowed funds and attempted to identify the many forms of family assistance as well as the importance of this assistance in establishing the new entrant in farming.

The purpose of this article is to describe the methods used to gather and analyze this information, and to report the results and conclusions of the study.

THE SURVEY AND THE QUESTIONNAIRES

The target population for this survey was new entrants who had started farming in Manitoba during the previous 3 years. This population was relatively large and difficult to identify. As a result, two sample populations were identified to represent the target population. The first consisted of diploma graduates from the University of Manitoba known to have started farming during the time period of the early 1980s. The second was made up of nondiploma graduates known to have started during the same time period. These were identified by agricultural representatives of the Manitoba Department of Agriculture.

During the summer of 1984, the two sample populations received mailed questionnaires with identical questions and a covering letter explaining the survey. Mailing was timed so that the questionnaire would be received between the busy seeding and haying seasons. Follow-up letters were sent to those who did not respond before a specified time. A second follow-up letter was sent where appropriate.

Because becoming a farmer is a matter of degree and is not well defined, all members of the sample were asked a series of questions regarding ownership or access to marketing rights, land and other productive resources to determine whether they in fact had started to farm. Further questions gathered information on the resources of the farm, how they were acquired, and if and how they were shared with family or others. A section of the questionnaire asked about family assistance, the form it came in, dependence upon it, and whether the family had incurred hardship in order to provide the assistance.

A section of the questionnaire was devoted to credit requirements of the new entrants; it asked how these had been met by both public and private lending institutions. New entrants were asked to describe how their farm operation was tied to the family farm operation and whether they had goals to farm independently. They were also asked about off-farm employment and whether this was a factor in establishing and/or continuing the farm operation.

Each individual surveyed was asked to volunteer more detailed information about farm finances through a follow-up questionnaire and interview. Those who agreed were contacted the following winter and provided this additional information through a questionnaire completed with the assistance of a personal or telephone interview.

During the following winter, respondents who agreed to provide this more detailed information were sent a second questionnaire, which followed the same line of questioning as the first but asked for details on specific family assistance, amounts of loans, sources of credit, repayment conditions, and problems encountered in these areas. The mailed questionnaires were completed with the assistance of either a personal interview or a telephone interview providing additional direction and interpretation.

RESULTS OF THE SURVEY

Response rate

Considering the personal and sensitive nature of this questionnaire, the response rate was considered very good. From a total of 396 possible respondents, 204 replied (51.5%). Furthermore, more than one third of the respondents agreed to the more detailed interview. As personnel and funds were not available for this many interviews, 40 names were randomly selected. However, when confronted with the detail of this second questionnaire, a number of people decided against the interview, leaving the study with 24 respondents to provide the more detailed information. Because this sample size was considered of inadequate size from which to draw conclusions, the analysis of this information was used only to reinforce or support conclusions drawn from the initial, more general questionnaire results.

Family assistance

At the time of the survey, only 23% of respondents were farming independently of their families. Of those who did, 64% had started as an independent farm unit. Of those who were still farming with their family, 55% believed they would be taking over the family farm. A subsequent question asking whether they "might" take over the family farm, rather than the more definite "would", increased the level of response to 94%. Only 32% stated that they wanted to take over the family farm as soon as possible, while the remainder indicated that they were in no hurry for the independence this would bring about.

Respondents were asked about the assistance received from the family. Slightly less than half (49%) received inheritances and gifts to help in getting started. A significantly higher proportion of beginning farmers received indirect assistance. A majority (77%) provided labor to the family farm in return for resources to carry out their own farming operations. Furthermore, 85% were able to borrow farm machinery from their families at no cost, and 77% had free use of some farm buildings.

The family provided a significant amount of direct loan assistance.

Table 1 summarizes the percentage of survey respondents receiving these various forms of family assistance and puts into perspective the significance of this family support toward entering farming. One third of all respondents obtained operating loans from their family and 30% received loans for capital items. There was considerable indirect loan support, as 43% had parents co-sign loans and 36% had secured loans with collateral provided by their parents. Some 73% of these beginning farmers stated it would not have been possible to start without the assistance. The sample was asked whether providing this assistance was a hardship on their families. Only 12% believed it was a serious hardship and an additional 39% felt that it had been a moderate hardship.

TABLE 1 RESPONDENTS RECEIVING VARIOUS TYPES OF FAMILY ASSISTANCE (%)

Type of assistance	Respondents answering the question	Respondents receiving the assistance
Inheritance and gifts received	98.5	49.3
Indirect assistance		
Labor for resources	98.5	77.1
Borrow machinery	99.0	85.1
Access to farm buildings	98.5	76.6
Loan assistance		
Direct loans		
Operating loan	97.5	33.2
Capital loan	98.0	30.5
Indirect backing		
Parent co-signs loan	98.0	43.0
Provide collateral	98.5	35.8
Possible to begin farming without assistance	94.1	26.6

A series of questions was designed to estimate the degree of dependence on the family for the capital-intensive resources such as land and machinery and to determine what proportion of the total farm operation in fact was operated by the new entrant (Table 2). The results show that most new entrants had acquired at least some land from their families and that in 61% of the cases more than half the machinery used in the total operation belonged to their families. The farming operation of the new entrant was half or less than half of the total family operation in 83% of the cases.

TABLE 2 RESPONDENTS WITH ACCESS TO FAMILY FARM RESOURCES (%)

Family farm resource	Respondents answering the question	Respondents using family resources in the following proportions: Zero	Less than one half	One half	More than one half
Land acquired from family and operated by new entrant	85.8	4.6	48.6	12.5	34.3
Machinery belonging to family	93.6	4.7	19.3	15.2	60.7
Portion of total operation operated by new entrant	78.9	1.2	60.9	21.1	16.7

In summary, information about new entrants and their families shows that for the most part the new entrant moved in under the umbrella of the parental farm unit; significant family assistance was received and was deemed necessary for the new farming operation. The fact that most did not consider that their families underwent serious hardship indicates that the family had the resources and the will to provide what appears to be a necessary role in bringing new farmers into the industry.

Availability and use of loans and grants

The sample was asked about their use of government lending programs and grants to start farming. Two thirds (67%) of respondents had obtained loans from government agencies and 9% had received government grants (Table 3). Fewer than half (47%) of the respondents said that government loans made up more than half their total borrowings to start farming. Government loans amounted to less than half the borrowings of 46% of respondents, and the rest said government loans made up about half.

TABLE 3 RESPONDENTS USING PUBLIC LENDING AND GRANTS PROGRAMS (%)

Public program	Respondents answering the question	Respondents using the program
Farm Credit Corporation Loan	99.0	19.1
Manitoba Agricultural Credit Corporation	99.5	38.4
Small Business Development Bond Loan	93.1	3.1
Government guaranteed loan	98.5	7.4
Government grant	99.0	9.4

A number of questions were asked to develop a picture of new entrants' use of private lending institutions. Most new entrants (78%) used the private institutions as a source of operating funds.

There was also considerable use of the private sector for loans for intermediate assets and real estate (Table 4). A more detailed distribution of sources of loans, size of loan and purpose of loan was obtained from the smaller and more detailed second survey (Table 5). This selected sample of 24 new entrants had borrowed a total of \$3 238 150 in 60 different loans. It is difficult to draw firm conclusions from this particular small sample, but it does show the magnitude of direct family loans relative to loans from both public and private lenders. It also shows that public institutions concentrating on real estate loans and private institutions are more active in providing intermediate loans and operating funds.

TABLE 4 RESPONDENTS USING LOANS FROM PRIVATE LENDING INSTITUTIONS (%)

Purpose of loan	Respondents answering the question	Respondents using the loan
Operating loan	98.5	77.6
Farm equipment loan	93.6	45.6
Livestock breeding loan	88.2	17.0
Real estate loan	76.5	19.9
Land improvement loan	76.5	9.6

Some respondents felt that larger loan limits, less equity requirements and more lenient repayment terms would lessen the need for family assistance (Table 6). Generally, respondents were equally divided on preference for public or private lenders, and only 22% felt that they were forced into bank loans because they had been unable to secure a government loan (Table 7). There was general agreement that government loans should be subsidized (90%), that repayment periods should be lengthened, and that interest rates should be lower. These answers are not surprising when it is considered that this group of new entrants started farming during a time period when interest rates had reached unprecedented levels.

In summary, new farm entrants appear to have been using both public and private lenders in their traditional capacity. There was very little use of government grants, and direct lending by family was a significant source of debt capital. New entrants did not have strong preferences for one source of credit over another, but did identify a perceived limitation in credit availability (size of loan) and repayment terms. They felt that less stringent credit programs could have eased the reliance on assistance from their families.

The importance of off-farm work

The first and more general questionnaire asked about the importance of off-farm work in getting established in farming. In a majority of cases (64%), either the new entrant or spouse worked off the farm. Of these families, 55% felt that the money they earned was very important to the operation of their farm and an additional 24% believed the money to be moderately important.

More detailed questioning of the second smaller sample revealed that 29% felt that they would not have been able to start farming without the off-farm job. The most prevalent use of earned off-farm income was for family living (57% of respondents). Most respondents recognized that off-farm work interfered with their ability to operate the farm at least to some

TABLE 5 DISTRIBUTION OF SOURCES AND PURPOSE OF LOANS

	Public institution		Private institution		
	Farm Credit Corporation	Manitoba Agricultural Credit Corporation	Banks	Suppliers	Family
Loans (number)	4	14	25	6	11
Range ($)	4 000–80 000	10 000–200 000	2 000–800 000	5 000–100 000	3 000–154 650
Mean ($)	62 500	74 050	56 640	36 750	28 050
Total value ($)	250 000	1 042 900	1 416 100	220 500	308 650
Purpose (%)					
Land	75	57.1	8	17	45.4
Equipment	0	0	36	67	36.3
Operating	0	0	28	17	0
Multiple	26	28.5	12	0	18.1

extent. While 70% said it only "partially" interfered, 6% did not qualify the extent of interference. The remaining 24% said it did not interfere at all. When asked whether they would quit off-farm work once they had become established farmers, 29% said no, 59% said maybe and 12% said yes. These results indicate significant dependence upon off-farm work to provide income for new farm entrants and a definite unwillingness to give it up, even after the dependence may diminish.

TABLE 6 RESPONDENTS ASSESSING IMPACT OF VARIOUS LOAN CHARACTERISTICS ON NEED FOR FAMILY ASSISTANCE (%)

Change in loan characteristic	Respondents answering the question	Respondents agreeing with the statement
Larger loan limit would reduce level of family assistance required	74.5	69.5
Reduced equity requirement for loan would ease family's burden in providing assistance	71.1	42.1
Smaller repayments would reduce level of family assistance required	95.7	62.1

TABLE 7 RESPONDENTS ASSESSING IMPACT OF PUBLIC AND PRIVATE LOANS (%)

	Respondents answering the question	Respondents agreeing with the statement
Interest rates on government loans should be subsidized	95.6	89.7
Repayment periods should be lengthened	92.2	55.8
Forced into bank loan because unable to secure a government loan	88.2	22.2

CONCLUSION

The main finding of this study is that new entrants are very dependent upon family assistance. This assistance comes in many forms and provides equity that allows the new farmer to enter with a leveraged position that can tolerate the instability inherent in agricultural prices and yields. It can also be concluded that the families providing this assistance were able to do so without incurring undue hardship.

There is, however, no assurance that this condition will continue. The farm economy could deteriorate to the level that assistance may be withdrawn. If this should happen, there would be a serious void in meeting entry requirements of new farmers.

The people surveyed felt that lending institutions could provide more lenient credit policies to take some of the responsibilities from their families. If this were to happen, the equity provided by family would be replaced by debt capital, and new farmers would be leveraged higher rather than lower. Policy changes in this direction may have to consider more stabilization programs to counteract the higher leveraged situation.

Another consideration may be to develop a policy to encourage and to make it easier for farm families to continue to provide the kinds of assistance identified in the study. The results indicate that this level of assistance was a factor in the apparent successful entry of the large majority of the sample, and that there was a lack of perceived hardship on families providing the assistance. These survey findings are evidence that it is an expedient and effective means of entry. It may be less costly to society to subsidize this status quo situation than to subsidize credit and/or stabilization programs in order to have an adequate supply of new farmers coming into the industry.

Continuation or enhancement of this status quo dependence upon family assistance may also enhance any existing barriers to entry facing those who do not come from existing family farms. The efficiency and performance of the farming sector may be hindered if new ideas and innovations become excluded along with this group of potential entrants. Policy makers may have to weigh this cost against the expediency of having farm families provide a larger share of the entry cost.

It can also be concluded that off-farm employment is a significant factor to both new and continuing farmers. The new entrants surveyed said they do not intend to give up this income and satisfaction, even after they have become established farmers.

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Some evidence on the incidence of financial stress in Canadian and American agriculture

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OVERVIEW

This report compares farm financial conditions between Canada and the United States as of January 1, 1985. In summary, the results show that the degree of financial stress was considerably higher in the U.S., using an evaluation of the cash flow differences as measured by the debt service ratio. An analysis based on the traditional debt-to-asset ratio, however, would suggest that there was no significant difference in the financial stress conditions faced by farmers in the two countries.

The analysis further shows that gross incomes, farm investment and debt levels were significantly higher per farm in Canada. Economic conditions that have occurred since 1985 have affected the relative changes in these variables. Between 1985 and 1986, the annual USDA survey revealed an average drop of 12% in farmland prices, compared with a 6.9% drop in Canada.[2] Preliminary forecasts for the United States suggest that land values may be stabilizing in 1987. Estimates suggest that in Canada, land price declines are expected to continue to decline for several years through 1988. Given the relatively high levels of Canadian farm investment and debt, there is the potential for proportionately greater asset and debt depreciation to occur in this country.

Based on this analysis, the economic adjustments, policy implications, and magnitude of institutional stress will be greater in Canada. It is important to note that there will be significantly greater adjustments required in specific sectors, such as the grains and oilseeds industry, relative to the livestock sector.

BACKGROUND AND OBJECTIVE

Economic conditions facing North American agriculture have changed greatly from the relative boom period of the 1970s. Media reports of farm bankruptcy, forced sales and deteriorating land values are common and have contributed to a general perception of widespread financial stress in agriculture. However, a large number of farmers continue to earn positive rates of return on their investment. Nevertheless, for a significant number of farmers, financial stress is severe, and their future in the sector is uncertain. This diversity of financial conditions is a distinguishing feature of today's agricultural industry. This requires policy makers to look at more than aggregate statistics to assess the sector's economic performance.

The objectives of this article are to review financial conditions of farmers in Canada and the United States and to provide an analysis of the level and nature of the differences.

DEFINITION OF FINANCIAL STRESS

Financial stress is a concept that has numerous interpretations. For the purpose of this analysis, the definition of financial stress employed is restricted by the variables jointly available on two surveys, the U.S. 1985 Farm Costs and Returns Survey and the Canadian 1984 FCC Farm Survey. Although the two surveys provide considerable information on financial indicators, each has a sufficiently different focus that an elaborate measure of financial stress cannot be jointly supported by the data. Consequently, the measures chosen for this analysis may be somewhat simplistic, but they do provide reasonable indicators of the general distribution of financial stress.

There are two principal elements to be considered in evaluating the financial status of an enterprise. The first is the collateral available to provide security for the debt obligations. The second is the ability of the borrower to maintain the flow of payments required to keep the loans current. In the first case, the asset base of the borrower and the value of outstanding claims on these assets serve as good indicators of security. Such indicators as net worth or the debt-to-asset ratio (DAR) are useful measures of security. The second element requires analysis of the income flow of the enterprise and the claims against income. Indicators such as cash balance, gross margin or net margins are often used to evaluate the ability to meet debt service obligations.

An alternative to these latter indicators is the debt service ratio (DSR), which provides a measure of available funds to cover principal and interest payments after other cash operating costs and living expenses are met from all sources of income. This is defined as:

$$\text{Expense debt service ratio} = \frac{\text{gross margin}^{3} + \text{off farm income - living}}{\text{interest and principal payments}}$$

The ratio is unbounded, with numbers larger than 1 indicating the availability of funds in excess of those required to cover all current debt obligations of the enterprise. A value between zero and 1 indicates that the enterprise has sufficient funds to cover some, but not all, of the current debt obligations.

A value of zero indicates that the enterprise can just cover operating expenses and living costs but cannot make any debt payments. A value less than zero indicates that the enterprise is unable to repay any of its debt obligations and cannot fully cover operating expenses and living costs out of gross receipts and off-farm income.

The DSR has the advantage of providing an indicator that is insensitive to farm size in terms of its ability to measure the flow level of current financial capacity. The use of either the cash balance or net margin produces some confusion in this respect, since the size of the operation must be taken into consideration in assessing its performance.

The DSR also has the advantage of focusing attention on the role of debt service in the enterprise. Given the current concern with farm debt levels and farmers' ability to maintain access to operating credit, the DSR provides a convenient summary statistic. It should be noted that the ratio, as defined, does not incorporate depreciation as a charge against income. Thus, it should be interpreted as a short-term indicator of financial performance.

DATA AND METHODOLOGY

The data sources for this comparison are the 1985 Farm Costs and Returns Survey (FCRS) conducted by USDA and the 1984 Farm Survey (FS) conducted by the Farm Credit Corporation of Canada. These two surveys provide the most accurate and comprehensive surveys of North American farm financial conditions available for comparison.

The period under review is the 1984 calendar year. The 1984 Farm Survey of Canadian financial conditions examined financial data from the year 1983. Adjustments based on Statistics Canada estimates have been made to update income and expense changes to 1984. The balance sheet data represent conditions as of January 1, 1985. Adjustments have been made to asset and debt values to reflect the situation as of January 1, 1985.

In organizing the presentation of the data, tables are set up on the basis of sales class and DARs. Farmers with DARs of less than 0.4 are considered to have sufficient equity in their enterprise that, on average, they will be able to continue in operation with few financial problems in the short run. Farmers with DARs between 0.4 and 0.7 are considered to be fundamentally viable but may need adjustments to allow them to restructure their operations to continue producing. Farmers with DARs greater than 0.7 are considered likely to be in severe financial stress. Only major amounts of assistance will allow them to continue in agriculture beyond the near term. Within this class, farmers with DARs greater than 1.0 are technically insolvent and, barring major injections of cash to allow them to service their debt, will be forced from the sector.[4]

The data are further classified into four sales classes:

- sales less than \$20 000 – part-time farmers;
- sales \$20 000 to \$60 000 – limited resource farms;
- sales \$60 000 to \$250 000 – commercial farms; and
- sales more than \$250 000 – large commercial farms.

The analysis presented within this article provides insights into the characteristics of farmers in Canada and the U.S. by DAR, DSR and by sales class. A more comprehensive analysis, which includes a breakdown by geographic region, has been completed and is available from the authors on request.

ANALYSIS

Financial stress conditions of all farms, Canada and U.S.

The data in Table 1 present a summary of financial information for the distribution of farms by sales class in the two countries. Comparison of the distribution of farms suggests that, while commercial farms with sales above $60 000 were represented by roughly the same proportion of farms in the two countries during the period of review, there was a greater proportion of farms with sales less than $20 000 in the U.S. than in Canada.

DAR comparisons

There was a remarkable consistency between average DAR by sales class among farms in the two countries. Also, the higher the level of sales, the larger the DAR.

There were some notable differences in the levels of assets and debt. Canadian farmers tended to have both higher asset values and higher debt levels than their American counterparts. Those differences were most apparent in those farms having sales of $20 000 to $60 000 and of $60 000 to $250 000, which can be considered the core of the sector in each country. Asset values were more than 25% higher in Canada, while debt was roughly 15% higher. The fact that U.S. real estate values have declined in the past few years to a greater degree than have Canadian values may explain much of these asset value differences. Given the potential for significant further declines in Canadian asset values, financial stress may become higher in this country.

From a security perspective, the net worth and debt-to-asset positions of farmers in Canada and the United States appear to have been roughly comparable. In addition, while DARs increased with higher sales levels, they were, on average, relatively small.

TABLE 1 FINANCIAL CHARACTERISTICS OF FARMS, CANADA AND U.S., 1984

	Sales class							
	United States				Canada			
	Under $20 000	$20 000 to $60 000	$60 000 to $250 000	Over $250 000	Under $20 000	$20 000 to $60 000	$60 000 to $250 000	Over $250 000
Farms in class	857 854	205 404	531 459	99 220	57 429	69 942	86 880	14 550
Share of all farms (%)	51	12	31	6	25	31	38	6
Cash sales	$6 378	$27 094	$101 024	$539 883	$9 189	$37 136	$115 545	$504 080
Operating expenses	$12 203	$33 841	$99 059	$516 087	$5 007	$20 211	$62 920	$311 350
Gross margin	$5 825	$6 747	$1 965	$23 796	$4 182	$16 925	$52 625	$192 720
Off-farm income	$19 468	$20 012	$9 752	$12 037	$15 763	$10 160	$5 708	$5 920
Residual	$13 643	$13 265	$11 717	$35 833	$19 945	$27 085	$58 333	$198 640
Living expense	$12 000	$12 000	$12 000	$12 000	$12 000	$12 000	$12 000	$12 000
Interest expense	$1 567	$4 084	$12 440	$47 792	$2 659	$6 446	$19 436	$55 290
Principal expense	$1 278	$3 342	$9 478	$35 321	$1 290	$3 093	$9 230	$22 940
Cash balance	$–1 202	$6 161	$22 201	$59 280	$3 996	$5 546	$17 667	$108 400
Total asset value	$149 180	$244 057	$447 569	$1 315 114	$184 702	$319 723	$614 389	$1 425 600
Total debt value	$14 860	$38 864	$110 214	$410 709	$18 343	$44 457	$134 042	$381 350
Net worth	$134 320	$205 193	$337 355	$904 405	$166 359	$275 266	$480 347	$1 044 250
Debt-to-asset ratio	0.10	0.16	0.25	0.31	0.10	0.14	0.22	0.20
Debt service ratio	0.58	0.17	–0.01	0.29	2.01	1.58	1.62	2.30

DSR comparisons

There were major differences in the DSR of farms in Canada, compared with those in the United States. In the United States, the average DSRs for all sales classes were less than 1.0, indicating that the average farm was unable to fully service its debt out of current receipts. In Canada, by contrast, all the average DSRs were above 1.5, which suggests that the average farmer was able to meet debt service obligations. This is particularly surprising, given the higher debt loads in Canada. The magnitude of the gap between the levels of the ratio in the two countries was so great that it cannot be readily explained by conceptual differences in survey design. This suggests that there may have been underlying structural differences in the two countries. Examination of interest and principal obligations confirms that they were larger in Canada than in the United States for each sales class. This is to be expected, given the higher debt level in Canada, but would suggest that debt service costs in Canada were higher than the observed pattern.

However, the sum of gross margin plus off-farm income minus living expenses is also important in explaining the difference in the DSR. The gross margin value for farms in Canada was far larger than the corresponding U.S. figure. The two smaller sales classes had positive gross margins in Canada and negative values in the U.S. Higher off-farm incomes in Canada in these two classes also indicates improved ability to service debt. In the two larger sales classes, off-farm income in Canada was lower than in the U.S. However, the gross margin of Canadian farmers was far in excess of that of their U.S. counterparts, a result of relatively lower operating costs and higher gross income in Canada.

This preliminary table suggests that there were fundamental differences between Canadian and U.S. agriculture. In particular, they seem to have revolved around the difference in levels of gross margin and in levels of debt and assets. These conditions are linked, since higher asset values in Canada can be readily explained by the capitalization of higher farm incomes into land values. Similarly, higher incomes allow for a greater use of debt. By looking at more disaggregate data, it is possible to develop a more refined picture of these differences.

Financial characteristics by sales class and DAR

Table 2 expands the analysis to break down sales classes by DAR. In Canada, in 1984, 5.0% of

TABLE 2 DISTRIBUTION, DEBT-TO-ASSET RATIO AND DEBT-SERVICE RATIO OF FARMS, CANADA AND U.S., JANUARY 1, 1985

	Canada DAR				United States DAR			
	Under 0.4	0.4 to 0.7	Over 0.7	All farms	Under 0.4	0.4 to 0.7	Over 0.7	All farms
Distribution of farmers by sales class (%)								
Over $250 000	65.6	24.7	9.7	6.4	63.0	22.0	15.0	6.0
$60 000 to $250 000	75.0	17.6	7.4	38.0	70.0	19.0	11.0	31.0
$20 000 to $60 000	86.4	9.2	4.4	30.5	80.0	11.0	8.0	12.0
Under $20 000	91.0	7.0	2.0	25.1	90.0	6.0	4.0	51.0
All classes	82.0	13.0	5.0	100.0	81.0	11.0	8.0	100.0
Average debt-to-asset ratios of farmers by sales class								
Over $250 000	0.15	0.52	0.91	0.27	0.15	0.52	1.05	0.31
$60 000 to $250 000	0.13	0.52	0.92	0.22	0.12	0.53	0.99	0.24
$20 000 to $60 000	0.08	0.53	0.88	0.14	0.08	0.53	1.06	0.16
Under $20 000	0.06	0.51	1.04	0.10	0.05	0.53	1.05	0.10
All classes	0.10	0.52	0.94	0.17	0.08	0.53	1.03	0.16
Debt service ratio of farmers by sales class								
Over $250 000	2.87	2.39	1.32	2.39	1.12	–0.23	–0.23	0.29
$60 000 to $250 000	2.4	0.93	0.79	1.62	0.82	–0.48	–0.73	–0.012
$20 000 to $60 000	2.52	0.65	0.32	1.58	1.58	–1.16	–1.18	0.17
Under $20 000	3.04	0.98	0.28	2.01	1.5	–0.24	–0.96	0.58
All classes	2.63	0.95	0.55	1.75	1.28	–0.42	–0.87	0.92

farms had a DAR greater than 0.7, compared with 8% in the U.S. The largest sales group, with sales more than $250 000 were in the worst financial shape, based on this criteria. In Canada, about 10% of farms had a DAR greater than 0.7, compared with 15% in the same class in the U.S. The middle portion of this table shows the remarkable consistency of DARs between the two countries in 1984, even when the population of farmers is disaggregated by both sales class and by DAR. Based on this criteria alone, it could be concluded that farm financial conditions and stress in the two countries were very comparable.

The lower portion of Table 2 suggests that the financial stress conditions between the two countries were very dissimilar, based on the DSR. In 1984, U.S. farmers had an average DSR of 0.92, which suggests that, as a population, the disposable income was not quite adequate to cover debt costs. A DSR of 1.75 for farms in Canada suggests a cash flow strength that was about double that of U.S. farms in 1984.

Relative comparisons of investment, debt and income levels

Table 3 summarizes relative differences in investment, debt and gross income between countries. The values in the table are found by dividing the Canadian average value by the equivalent U.S. value. A value of 1.25 suggests that the Canadian value was 25% greater than the corresponding U.S. value.

From an investment perspective (upper portion of Table 3), with the exception of farms with sales greater than $250 000, Canadian per-farm investment was significantly higher. Only for this larger-scale group were the investment levels roughly equivalent. Similarly, Canadian debts and incomes were significantly higher for all farm sales classes, with the exception of the farms in the largest sales class.

CONCLUSIONS AND OBSERVATIONS

There was a remarkable parallel between the DARs of farms by sales class in Canada and the United States in 1984. This ratio is maintained, although the asset and debt values for farms was significantly higher in Canada. This is likely a consequence of more favorable prices and sales volume of commodities for Canadian farms in recent years, particularly in the grains sector, relative to U.S. farms. It follows that these higher levels of gross sales allowed Canadian farmers to capitalize the asset values and to increase the use of debt relative to the experience of the U.S. farmers. Based solely on the traditional DAR, one would conclude that the level of financial stress between the two countries in 1984 was equivalent.

TABLE 3 RELATIVE INVESTMENT, DEBT AND GROSS INCOME RATIOS OF FARMS, CANADA AND U.S., JANUARY 1, 1985[1]

	Debt-to-asset ratio			
	Under 0.4	0.4 to 0.7	Over 0.7	All farms
Canada/U.S. investment ratio by sales class:				
Over $250 000	1.09	0.99	0.99	1.08
$60 000 to $250 000	1.36	1.26	1.37	1.37
$20 000 to $60 000	1.28	1.17	1.83	1.31
Under $20 000	1.23	1.32	1.46	1.23
Canada/U.S. debt ratio by sales class:				
Over $250 000	1.08	0.99	0.85	0.93
$60 000 to $250 000	1.5	1.24	1.20	1.22
$20 000 to $60 000	1.33	1.17	1.55	1.15
Under $20 000	1.38	1.27	1.45	1.20
Canada/U.S. gross income ratio by sales class:				
Over $250 000	0.90	1.17	0.72	0.93
$60 000 to $250 000	1.14	1.08	1.29	1.15
$20 000 to $60 000	1.37	1.39	1.28	1.37
Under $20 000	1.50	1.50	1.13	1.50

[1] All values are calculated by dividing the Canadian average value by the equivalent U.S. value. A value of 1.09 means the Canadian value is 9% larger than the U.S. value, etc.

The DSRs were considerably higher in Canada for most classes, suggesting that at the time of the survey these farmers were in a stronger cash flow position and were better able to meet operating and living costs and service debt when due. U.S. farmers, as shown by the analysis, were in a much weaker cash flow position. This increased level of stress, as shown by the DSR, has likely been a factor in the more significant declines in real estate values over the past several years in the U.S.

The great difference in levels of operating expenses and incomes between Canadian and U.S. farmers was clearly the cause of much of the difference in DSRs. The cause of the difference is critical in evaluating the comparative conditions of the sector in each country. A number of factors can be advanced as contributors to the differing levels of income and operating costs. At present, it is difficult to estimate their magnitude, but they should be evaluated in future research. Some of the factors that may have contributed to DSR differences were:

- higher levels of farm income in Canada resulting from exchange rate advantages, particularly in the cereal and livestock sectors;
- more reliance on administered pricing in Canada, whereby margins were guaranteed by cost-of-production pricing formulas or some other "cost plus" pricing schemes;
- a greater degree of specialization in the United States, resulting in an increased use of purchased inputs, which would have raised operating costs; and
- a higher incidence of rented land in the U.S., which would have increased operating costs if rented on a cash basis or would have reduced cash receipts if rented on a share basis (in either case, the effect would have been to raise the ratio of operating expense to cash sales).

With increases in DAR, the level of farm investment is generally found to have declined and the level of gross sales to have increased. In effect, highly leveraged farms were more productive in terms of sales revenue per dollar invested. However, the ratio of debt to sales also reached critical levels in most categories, suggesting an exposure to a high level of financial and business risk.

The DSR can be a very significant tool for identifying differences in levels of financial stress between the two countries. Generally, in the U.S., only farmers with a DAR of less than 0.4 had a positive DSR. In Canada, as of 1985, most farmers on average had a positive DSR and, for most debt-to-asset classes, the ratio was greater than 1. This indicates an ability to service all their debt payments, at least in the short run.

One conclusion that may be reached from these data is that the traditional DAR is of relatively minimal usefulness in assessing the financial position of a farm business. As is shown, the DARs were almost identical across borders. However, the degree of financial stress was dramatically different, based on the results of the DSR and through observations of adjustments taking place in the U.S. In Canada, considerable variance of opinion exists for the number of farmers in financial distress. In part, this confusion results from different risk criteria and overreliance on the DAR by some analysts.

In general, the degree of financial risk was found to be significantly higher in the U.S. than in Canada in 1984. This was generally the result of lower incomes and higher expenses in the U.S. These consequences have led to a more dramatic decline in asset values in the U.S. as they adjusted into equilibrium with net income.

Canadian agriculture appears to be in a more vulnerable position with respect to the expected downside risk it will likely experience over the next several years. Both its debt and asset values are high by U.S. standards. This is a partial consequence of the relatively high gross incomes and lower expenses of recent years. Subsequent declines in incomes in Canada, particularly in the grains sector, have led to a decline of asset values, resulting in eroding equity. Debt values in the short term will not significantly adjust downward. However, increasing and continuing financial stress will eventually adjust these debt values downward either through repayment or through default. This will place significant stress on financial institutions because of higher loan losses and greater pressure to increase agricultural interest rates.

It is important to note that the farms in the two countries that were the most comparable in terms of investment level, debt usage and income operation in 1984 were large farms with gross sales greater than $250 000.

1 Ralph Ashmead is Manager, Research and Development, for the Farm Credit Corporation in Ottawa. David Freshwater is a special adviser to the Economic Research Service of the United States Department of Agriculture in Washington, D.C. This article is a condensed version of a more comprehensive analysis available from the authors on request.

2 Farm Credit Corporation, Trends in Farmland Values, No. 20, December 1986

3 Gross margin is defined as cash receipts minus cash operating expenses, excluding depreciation and intermediate and long-term interest expense.

4 While the characterizations above are representative of the situation confronting most farmers, certain individual enterprises can be expected to deviate from the general trend.

IN REPLY TO AUTHORS AND EDITORS REGARDING VOL. 21 NO. 2

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CONVERSION FACTORS

Metric units	Approximate conversion factors	Results in:
LINEAR		
millimetre (mm)	x 0.04	inch
centimetre (cm)	x 0.39	inch
metre (m)	x 3.28	feet
kilometre (km)	x 0.62	mile
AREA		
square centimetre (cm^2)	x 0.15	square inch
square metre (m^2)	x 1.2	square yard
square kilometre (km^2)	x 0.39	square mile
hectare (ha)	x 2.5	acres
VOLUME		
cubic centimetre (cm^3)	x 0.06	cubic inch
cubic metre (m^3)	x 35.31	cubic feet
	x 1.31	cubic yard
CAPACITY		
litre (L)	x 0.035	cubic feet
hectolitre (hL)	x 22	gallons
	x 2.5	bushels
WEIGHT		
gram (g)	x 0.04	oz avdp
kilogram (kg)	x 2.2	lb avdp
tonne (t)	x 1.1	short ton
AGRICULTURAL		
litres per hectare (L/ha)	x 0.089	gallons per acre
	x 0.357	quarts per acre
	x 0.71	pints per acre
millilitres per hectare (mL/ha)	x 0.014	fl. oz per acre
tonnes per hectare (t/ha)	x 0.45	tons per acre
kilograms per hectare (kg/ha)	x 0.89	lb per acre
grams per hectare (g/ha)	x 0.014	oz avdp per acre
plants per hectare (plants/ha)	x 0.405	plants per acre

Canada